VOLUME VII JUNE, 1914 No. 2

THE TREMATODE PARASITES OF NORTH QUEENSLAND. II. PARASITES OF BIRDS.

BY WILLIAM NICOLL, M.A., D.Sc., M.D.

(*Australian Institute of Tropical Medicine, Townsville, Queensland.*)

(With Plates VI and VII.)

CONTENTS

In the first part of this paper fifteen species were described, eight of which were from birds. In the present part an additional fifteen are dealt with.

During the course of the past year one hundred and fourteen birds belonging to fifty different species were examined. Of these, seventy-seven were found to be infected with parasitic worms. The latter comprise a considerable variety of forms and number close upon a hundred different species.

Although, however, there is a great wealth of parasitic material, it does not display much that is of outstanding interest or peculiarly Australian. This is not altogether surprising in view of the fact that a considerable number of Australian birds are migrants. Their parasites

are, in consequence, in many cases identical with, or very closely related to, those which occur in the same or similar birds in Europe and Asia. This is well illustrated by the common occurrence of such widely distributed parasites as *Echinostomum revolutum* (Froelich) and *Notocotylus attenuatus* (Rud.).

With one exception (*Allopyge antigones* S. J. Johnston) all the trematode parasites hitherto described from Australian birds have been referable to already known genera. The same applies to the species described in the present paper with the exception of two liver-flukes from the stone-curlew and white ibis. Though closely related to corresponding European forms (*Platynosomum*) they display characters sufficiently distinctive to warrant their being regarded as members of a separate genus.

The most characteristic feature of the Australian bird Trematode fauna is the comparative frequency with which Echinostomes and Holostomes occur. Specimens of these two groups have been collected from eighteen and a dozen different birds respectively.

In addition to the species described here a number of other forms have been collected but either on account of immaturity or imperfect condition they do not admit of sufficiently accurate determination and description. Amongst these may be mentioned an interesting form from the Spur-wing Plover, apparently a member of the Lepodermatidae, and a species of *Prosthogonimus* from the peewit (*Grallina picata*).

DISTOMATA.

Family **Opisthorchiidae.**

Opisthorchis obsequens n. sp.

(Plate VI, fig. 1.)

About fifty specimens of this form were obtained from the liver of a brown hawk (*Hieracidea berigora*). A few immature specimens (about 1 mm. long) were also obtained from the liver of *Hieracidea orientalis*. The adult specimens vary in size from 2·6 to 5·1 mm. The maximum breadth, which occurs in the post-acetabular region, varies from 0·8 to 1·2 mm. An average specimen measures 3·7 × 1·0 mm. The body is very much flattened and the edges are crenated. The anterior end is considerably attenuated but the posterior end is rounded. Frequently, however, a small knob-like tip projects from the posterior end. There are no cuticular spines. The oral sucker is almost terminal

and measures $0·16 \times 0·20$ mm. in an average specimen. Its transverse diameter varies from 0·15 to 0·24 mm. The ventral sucker measures 0·26 mm. and it is situated 1·24 mm. from the anterior end, *i.e.* exactly one-third of the body length.

There is no prepharynx. The pharynx has a diameter of 0·12 mm., and is slightly longer than broad. The oesophagus is about 0·19 mm. in length (0·13 to 0·29 mm.). The intestinal diverticula are sinuous and narrow and their walls are crenated, especially on the inner side. They extend to within 0·2 mm. of the posterior end of the body. Their ends are turned in towards the middle line.

The excretory vesicle has the usual sinuous configuration observed in species of this genus. The posterior curve may be either towards the right or the left. The bifurcation occurs just behind the ovary and the limbs are short.

The genital aperture is median and immediately in front of the ventral sucker. The vesicula seminalis is short and highly convoluted. It extends beyond the ventral sucker for a distance of about 0·3 mm. The testes are very much lobed, almost dendritic. There are usually five lobes on the anterior testis and four on the posterior; but this is not invariable. They are more or less tandem, but there is always a tendency to obliquity, the anterior testis being usually displaced towards the left side. Amphitypy occurs fairly frequently. The post-testicular space measures 0·34 mm., *i.e.* about one-eleventh of the body length.

The ovary lies a short distance in front of the testes and is almost median. It is also excessively lobed, there being usually three lobes directed backwards. It is much smaller than either of the testes. Alongside and slightly behind it lies a pear-shaped receptaculum seminis, usually on the right side. It is of moderate size. The yolk glands extend from the level of the middle of the ventral sucker to the level of the anterior testis. Usually they reach the middle of the testis but occasionally they stop at its anterior border. They lie entirely to the outer side of the intestinal diverticula and consist of eight groups of follicles on either side. The transverse yolk ducts meet at a very obtuse angle in front of the ovary. The uterus fills up the space between the ovary and the ventral sucker. It forms 14–16 transverse convolutions which occasionally touch, but do not overlap, the intestinal diverticula. The numerous ova measure 0·025 to $0·030 \times 0·014$ to 0·017 mm., the average being $0·028 \times 0·0155$ mm.

This species is distinguished from other members of the genus by the excessively lobed condition of the testes, a condition which almost

8—2

approaches that found in *Clonorchis*. The ovary is also of an unusually irregular outline. The ventral sucker is larger than in most other species while the yolk glands are more continuous.

The genus *Orchipedum* occupies at present an ill-defined systematic position. Braun (1902) regarded it as a possible member of the *Psilostomidae*, but this view is not endorsed by Odhner (1913, p. 304) who considers the genus to be more closely allied to *Paragonimus*. The anatomy of the species I am about to describe supports his conclusions so far as they go, but at the same time it can hardly fail to be apparent that the relationship between these two genera is not of a very intimate character.

Orchipedum sufflavum n. sp.

(Plate VI, figs. 2, 3, and Plate VII, fig. 13.)

Two specimens of this interesting parasite were met with in the oesophagus of a black spoon-bill (*Platalea regia*). It is a large brightly coloured species, the ground colour being light yellow and the margins dark brown. In addition the compact mass of eggs forms a large reddish-yellow spot in the anterior part of the body.

The outline is somewhat lozenge-shaped, the greatest breadth occurring at the anterior third of the body, a little behind the ventral sucker. From there the body tapers rapidly towards the anterior end. Both ends are pointed. The edges of the body are very thin and are thrown into irregular wrinkles. There are no cuticular spines.

The length is 11·3 mm. and the maximum breadth 2·8 mm. The oral sucker is globular, with a diameter of 0·9 mm. The shallow ventral sucker is somewhat oval and measures 1·37 × 1·61 mm. It is situated 2·5 mm. from the anterior end.

The pharynx is contiguous with the oral sucker and there is practically no oesophagus. The intestinal diverticula extend almost to the posterior end of the body and are rather inflated and irregular.

The excretory vesicle is Y-shaped, the bifurcation taking place a short distance behind the level of the ovary.

The genital aperture is median and almost midway between the two suckers. There is no true cirrus-pouch but the vesicula seminalis is of comparatively large size and extends back to beyond the middle of the ventral sucker. It is slender and highly convoluted. The pars prostatica is somewhat elongated and is surrounded by a very large number of prostatic cells, forming an almost globular body. It is not

enclosed by any muscular or fibrous membrane. The ductus ejaculatorius is very short. The testes are extremely numerous and fill up almost the whole of the median field of the post-acetabular region. They are separated from the ventral sucker by the first convolution of the uterus, and they extend back to a point about 1·7 mm. from the posterior end. Each testicle is small, transversely oval and fits closely against the adjoining testicles. The outermost testicles overlap the intestinal diverticula to a slight extent. Posteriorly the testicles are disposed in a single layer but anteriorly they are in two layers.

The ovary lies close behind the ventral sucker on the right side or the left. It is a moderately large transversely oval body. Behind it and dorsally lies a small horse-shoe shaped receptaculum seminis separated from it by the transverse yolk-duct. The receptaculum seminis gives off Laurer's canal direct and the latter is remarkable for its unusual width and muscular development. It is somewhat convoluted but of no great length. The short duct from the receptaculum seminis unites with the oviduct to form the ootype, which is short and curved. The yolk glands are extremely voluminous. They are lateral and extend in a broad band from the level of the pharynx to near the tip of the tail, where, however, they do not unite. These lateral bands lie to the outer side of the intestinal diverticula, but overlap them to some extent both dorsally and ventrally. In addition there is an internal row on each side, situated on the inner side of the diverticula and dorsal to the testes. This internal row, however, only extends halfway from the tail to the ventral sucker and is discontinuous in places. The outer and inner bands of follicles are connected by short transverse ducts passing dorsal to the intestinal diverticula. The uterus is short but wide and contains a considerable number of eggs. In its course it passes thrice across the body, dorsal to the ventral sucker. The terminal part of the uterus has its walls thrown into curious regular folds (seen in fig. 13). The vagina issues from this part as a short, narrow tube running straight to the genital aperture. The eggs are golden yellow in colour and measure 0·07 to 0·075 × 0·04 to 0·045 mm.

Family **Echinostomidae.**

Sub-Family **Echinostominae.**

Echinostomum acuticauda n. sp.

(Plate VI, fig. 4.)

A considerable number of specimens of this parasite were found in the cloaca, rectum and lower intestine of the straw-necked ibis (*Carphibis spinicollis*). It is a long, narrow, flat and delicate species, from 9 mm. to 12 mm. in length. The breadth is fairly uniform, 0·9 to 1·0 mm., *i.e.* about one-eleventh of the length. The tail terminates in a very sharply pointed tip. The width of the head is 0·6 mm. and there are 37 cephalic spines measuring 0·1 to 0·112 × 0·03 to 0·035 mm. The neck is closely set with cuticular spines. Behind the ventral sucker to the level of the testes there are a number of small scattered spines. These disappear from the margins of the body not far behind the sucker and are also absent on the dorsum.

The oral sucker measures 0·2 to 0·21 mm. in diameter. The ventral sucker is deep and measures 0·7 to 0·77 × 0·56 to 0·63 mm., the average being 0·73 × 0·59 mm. It is situated at a distance of 1·2 to 1·5 mm. from the anterior end, *i.e.* a little more than one-eighth of the body length. The oval pharynx measures 0·18 × 0·14 mm. and the oesophagus 0·43 mm. The diverticula are continued to near the posterior end.

The genital aperture is situated over the intestinal bifurcation. The cirrus-pouch is stout and nearly reaches the centre of the ventral sucker, on the dorsal surface of which it lies. Its dimensions are 0·4 × 0·3 mm. It contains a large convoluted vesicula seminalis, a small pars prostatica and a short ductus.

The small round ovary is situated at a distance varying from 0·9 mm. to 2·45 mm. behind the ventral sucker. On an average the distance is 1·5 mm. It measures 0·23 × 0·27 mm. The anterior testis is about 0·25 mm. behind the ovary and it is separated from the posterior testis by a space of about 0·1 mm. The testes are long, narrow and somewhat sinuous. Their edges are much indented. The posterior testis is invariably the larger. On an average they measure 0·83 × 0·37 mm. and 0·96 × 0·33 mm. respectively. The distance from the posterior testis to the tip of the tail is 4·05 to 4·75 mm. (average 4·33 mm., or exactly three-sevenths of the body length).

The yolk glands are entirely lateral, extending from a short distance (0·25 mm.) behind the ventral sucker to a point about 0·35 mm. from the tip of the tail. They increase very gradually and regularly in width, starting with a single follicle at the anterior end, they immediately increase to two follicles in breadth. Behind the ovary the number is increased to three, while behind the testes it reaches a maximum of four, and the breadth is uniform throughout the post-testicular space. At the level of the ovary the width of the yolk glands is 0·18 mm.; in the post-testicular space it is 0·28 mm. In the latter region there is an unoccupied space 0·3 mm. in width.

The ova are of large size, but few in number. They measure 0·112 to 0·126 × 0·063 to 0·075 mm. (average 0·118 × 0·069 mm.).

This is the fifth avian Echinostome with 37 cephalic spines, which has been described. *E. revolutum* (Froelich) has already been recorded from Australian ducks and is not at all uncommon in Queensland. Although bearing much resemblance to the present species in internal anatomy it is altogether a much broader and bulkier form. *E. mendax* Dietz bears an even closer resemblance, but it again is a broader and plumper species. Its length is only six times its breadth, the testes are considerably smaller, the cephalic spines and the ova are decidedly smaller while the post-testicular space is much shorter. *E. paraulum* Dietz again is a much smaller and broader species and differs from the present species in many other respects. The same applies to the immature *E. echinocephalum* Rud.

Echinostomum emollitum n. sp.

(Plate VI, fig. 5.)

Several specimens of a small delicate Echinostome were found in the intestine of a pheasant coucal (*Centropus phasianus*). The specimens, which were all mature, measured 4·5 to 6·7 mm. in length and 0·55 to 0·70 mm. in breadth. The length is thus about nine times the breadth. The whole body is very thin and transparent. The head is particularly small and measures only 0·27 mm. in diameter. There are 35 cephalic spines. Those of the end group are constantly larger than the others, measuring 0·045 to 0·057 mm. Next to them are the smallest spines and the length increases gradually on passing dorsally. The length of the marginal spines is 0·030 to 0·042 mm. The neck is thickly beset with small spines and these are continued back to the level of the testes. Their distribution, however, behind the ventral sucker is very sparse.

The oral sucker has an average diameter of 0·11 mm. The ventral sucker measures 0·34 × 0·27 mm. and it is situated at a distance of 0·74 mm. from the anterior end of the body. The neck is therefore about one-eighth of the length of the body.

The pharynx, which is contiguous with the oral sucker, measures 0·11 × 0·09 mm. The oesophagus extends half way to the ventral sucker and the diverticula pass out widely round it. The genital aperture lies over the intestinal bifurcation. The cirrus-pouch is plump and extends back to about the middle of the ventral sucker. The ovary is situated about 1·8 mm. (*i.e.* one-third of the body length) behind the ventral sucker, but there is considerable variation in its position. It is a small transversely oval body measuring 0·2 mm. in greatest diameter. The anterior testis is separated from the ovary by a space of 0·4 mm. It is an elongated oval body with pointed ends and measures 0·55 × 0·25 mm. The posterior testis is usually almost contiguous with the anterior testis but is sometimes separated from it by quite a considerable distance. It has a similar shape but is slightly smaller. The post-testicular space comprises about one-sixth of the body length.

The yolk glands extend from a short distance behind the ventral sucker to near the tip of the tail. They are moderately well developed and do not unite in the post-testicular space. The uterus occupies the usual position and the eggs measure 0·100 to 0·115 × 0·052 to 0·056 mm.

This species is rather like *E. elongatum* Nicoll but is distinguished from it by its small head and the more delicate texture of the body.

Echinostomum hilliferum n. sp.

(Plate VI, fig. 6.)

Four specimens of this large Echinostome were obtained from the duodenum of a bald coot (*Porphyrio melanotus*). Of a deep brick red colour, the body measures 14·5 to 16 mm. in length. It is thick and fleshy with the margins thrown into irregular wrinkles. The maximum breadth occurs a little behind the ventral sucker and measures 1·7 to 2·2 mm. The breadth of the head, which is moderately well expanded, is 1·1 to 1·2 mm.

The cephalic spines number 47, and comprise the usual end groups of five each with 37 marginal spines arranged in two unbroken rows. In the end groups there are two large spines overlying three smaller ones; the former measure 0·154 × 0·05 mm., the latter 0·10 × 0·04 mm. The marginal spines are intermediate in length and measure on an

average 0·115 × 0·042 mm. Cuticular spines, of small size, are present on the neck as far back as the anterior border of the ventral sucker. Behind the sucker the skin is entirely devoid of spines.

The globular oral sucker has a diameter of 0·4 to 0·45 mm. The large ventral sucker is funnel shaped and measures 1·2 mm. in diameter by 1·6 mm. in length. Its centre lies at a distance of 2·5 to 3·1 mm. (average 2·8 mm.) from the anterior end of the body.

There is a distinct prepharynx about 0·13 mm. in length, a pharynx measuring 0·39 × 0·28 mm. and an oesophagus of 0·84 mm. (0·75 to 1·0 mm.) in length. The diverticula extend to near the posterior end of the body.

The genital aperture lies over the intestinal bifurcation. The massive cirrus-pouch is about 0·85 mm. long and contains a large, slightly constricted vesicula seminalis. The cirrus is of considerable length and was found in one specimen exserted to a distance of 2 mm.

The ovary lies 2·0 mm. (1·8 to 2·2 mm.) behind the ventral sucker. It is an almost globular body with a diameter of 0·5 mm. Immediately behind it lies a large shell-gland. The anterior testis is separated from the ovary by a space of 0·8 mm. (0·6 to 1·0 mm.). The two testes are contiguous or even overlapping. They are of large size and peculiar shape. They are about equal in size and measure on an average 1·2 × 0·7 mm. The peculiar shape may be imagined to be due to the testes being crushed in the direction of their long axes, so that their outline is thrown into twists, or convolutions. The number of these twists is practically constant, namely four half-turns. There are thus on either side of each testis two deep furrows. The anterior pole of each testis is usually directed towards the right side, but it may be reversed. The post-testicular space is, on an average, 4·2 mm. in length.

The yolk glands extend from a short distance in front of the posterior border of the ventral sucker to about 0·4 mm. from the tip of the tail. They are fairly voluminous in the post-testicular space but do not unite, nor do they overlap the testes to any great extent. The uterus contains about 100 fairly large eggs measuring 0·12 to 0·13 × 0·07 to 0·075 mm.

This species bears an exceedingly close resemblance to *E. australasianum* Nicoll. The most striking difference, perhaps, is in the shape of the testes. In *E. sarcinum* the elongated testes show a number of simple constrictions; in *E. australasianum* the testes are much smaller and are marked by a simple constriction across their middle. The great variation, however, which such a species as *E. revolutum* (Froelich)

may display in the shape and size of the testes must make one pause in placing undue weight on these as specific characters. *E. sarcinum* presents the further difference of having a ventral sucker of which the breadth exceeds the length. Other minor points of difference are: (1) In *E. sarcinum* the cephalic spines of the end groups are all equal in size. (2) The suckers are slightly smaller in proportion to the size of the species. (3) The testes are decidedly smaller. (4) The yolk follicles are much smaller and the eggs slightly so. It is apparent that apart from the testes and the ventral sucker, which are at best somewhat unreliable as distinctive features, the differences between the two species are of an essentially minor character. Although Dietz appears to do so, I am not inclined to attach much importance to the difference in the cephalic spines. In the four specimens at present under consideration it so happens that the arrangement I have described is approximately constant but that has not been my experience with other species. The difference of host is of more significance in regarding these two forms as specifically distinct.

In *E. australasianum* the ventral sucker is even more elongated than in the present species, the ratio of the length to the breadth being almost 2 : 1 instead of 4 : 3. The testes, too, in addition to having a different shape, are very much smaller.

Echinostomum ignavum n. sp.

This is a small species, the distinguishing characteristic of which is the number of cephalic spines. There are 29 altogether, four of which form a terminal group at each end of the row. These terminal spines are separated from the others by a well marked space. The length of the terminal spines is 0·084 mm.; of the other spines 0·065 to 0·07 mm.

Half a dozen specimens were collected from the intestine and caeca of a spur-wing plover (*Lobivanellus lobatus*). Only one of these was mature. It measured 2.8 mm. in length. The oral sucker has a diameter of 0·15 mm.; the ventral sucker measures 0·49 × 0·42 mm. and is situated 0·7 mm. from the anterior end. The large pharynx measures 0·17 × 0·11 mm. Cuticular spines are present and extend back a short distance beyond the ventral sucker. The breadth of the head is 0·38 mm. and the maximum breadth of the body is 0·6 mm. The yolk glands are rather scanty and extend from the posterior border of the ventral sucker to the tip of the tail. The ovary lies 0·55 mm.

behind the ventral sucker. The testes and ovary are of small size. The cirrus-pouch is plump and extends back to near the middle of the ventral sucker. The few eggs measure 0·095 to 0·100 × 0·05 mm.

Echinostomum revolutum (Froelich).

This species has already been recorded from North Queensland in *Anas superciliosa* by S. J. Johnston (1913). I have found it again in the same host as well as in the magpie goose (*Anseranas semipalmata*) and the black swan (*Chenopsis atrata*). A single specimen was also taken from the intestine of the green goose teal (*Nettopus pulchellus*).

Patagifer bilobus (Rud.).

An additional Australian host of this parasite is the straw-necked ibis (*Carphibis spinicollis*) from the intestine of which half a dozen specimens were collected.

Sub-Family **Echinochasminae.**

Echinochasmus prosthovitellatus n. sp.

(Plate VII, fig. 7.)

A considerable number of specimens of this peculiar Echinostome were obtained from near the posterior end of the intestine of a brown hawk (*Hieracidea orientalis*). It is a small plump form measuring 2 to 2·4 mm. in length. It is broadest in its posterior third where it may attain a breadth of 0·75 to 0·9 mm. The tail is acutely pointed. The breadth of the head is almost constantly 0·28 mm. The thickness of the posterior part of the body is about half the width, but the neck is more flattened and slightly hollowed out ventrally.

The cephalic spines number 24 and measure 0·05 to 0·055 mm. in length. The row of spines is not continuous dorsally but is interrupted by a median dorsal space measuring 0·077 mm. in breadth. The whole of the body, both dorsally and ventrally, is beset with large powerful spines which extend right to the tip of the tail.

The oral sucker measures 0·11 to 0·14 mm. and the ventral 0·38 to 0·45 mm., the rate being 3 : 10. Both suckers are globular. The ventral sucker is situated at a distance of 0·65 to 0·92 mm. (*i.e.* approximately three-eighths of the body length) from the anterior end.

The pharynx is somewhat larger than the oral sucker and measures on an average 0·15 × 0·13 mm. There is a short prepharynx. The

oesophagus is about 0·25 mm. long. The intestinal bifurcation occurs just in front of the cirrus-pouch and the wide diverticula extend to near the tip of the tail. They are almost entirely obscured by the yolk glands.

The excretory vesicle bifurcates dorsal to the posterior testis.

The genital aperture is situated a little in front of the ventral sucker. The cirrus-pouch is of comparatively large size and extends well past the middle of the ventral sucker. It contains a very large vesicula seminalis, which is divided into a large oval proximal part and a smaller globular distal part. It fills the greater portion of the pouch. The pars prostatica is small and globular and the ductus is short.

The testes are very large and fill almost the whole of the post-acetabular region. Their position is somewhat inconstant. In some cases the anterior testis touches the ventral sucker; in others it may be as much as 0·2 mm. behind it, the average being probably about 0·15 mm. The post-testicular space varies correspondingly (0·25 to 0·35 mm.). The testes are of somewhat irregular shape but, roughly, the anterior one is transversely oval while the posterior is somewhat heart-shaped or trilobate, the apex being directed backwards. They are always closely opposed and may even overlap. Their size varies but is generally about 0·45 × 0·65 mm.

The ovary is also variable in position. Usually it is crushed in between the ventral sucker and the anterior testis, both of which it overlaps. It is generally on the right side. In some cases, however, it lies entirely dorsal to the anterior testis and may be displaced backwards some considerable distance. In such cases the anterior testis usually touches the ventral sucker. The ovary is a small globular or ovoid body measuring 0·16 × 0·2 mm. There is no receptaculum seminis, but the initial part of the uterus is filled with sperms. The yolk glands are very extensive, extending almost the whole length of the body from the level of the pharynx to the tip of the tail. They are chiefly lateral, but in the neck they form a continuous dorsal layer between the pharynx and the middle of the ventral sucker. They overlap the testes to some extent but they do not unite in the post-testicular space. The eggs are very scanty, the greatest number in any one specimen being 18. They measure 0·086 to 0·191 × 0·049 to 0·055 mm. the average being 0·089 × 0·053 mm.

This species bears an extremely close resemblance to *E. bursicola* (Crepl), so close indeed that the specific differences are extremely minute. In the first place, however, the habitat is different. *E. bursicola*

appears to be exclusively an inhabitant of the *Bursa Fabricii* while *E. prosthovitellatus* lives in the terminal part of the intestine. The latter, again, is a somewhat large species, for in *E. bursicola*, egg production begins when the parasite is only 1 mm. long, while in *E. prosthovitellatus* many specimens over 2 mm. long were without ova. The latter species is also comparatively broader, the maximum breadth being always more than one-third of the length. On the other hand the head is distinctly narrower. The cephalic spines are a trifle larger. The suckers are larger and more unequal and the pharynx also is larger. The ventral sucker is, in addition, much nearer the centre of the body. Perhaps the most striking difference and that most easy of apprehension is the fact that the cirrus-pouch extends well past the centre of the ventral sucker and is not displaced to one side. In the yolk glands there are two noticeable features of difference. In *E. bursicola* the anterior dorsal layer does not extend so far back and the glands are fused in the post-testicular space. The latter condition, however, is sometimes met with in *E. prosthovitellatus*. Finally the eggs in *E. bursicola* are decidedly smaller. It is thus evident that in spite of the extremely close superficial resemblance there are several points of difference, the most outstanding of which, perhaps, are the position of the ventral sucker, the length of the cirrus-pouch and the disposition of the yolk glands.

Chaunocephalus ferox (Rud.).

A single specimen of this parasite was found in the intestine of a jabiru (*Xenorhynchus asiaticus*). It does not entirely agree with Dietz's description (1910, p. 475) of the species. The oral sucker is decidedly larger, having a diameter of 0·2 mm.; the ventral sucker is also somewhat larger. The terminal cephalic spines are much longer and more prominent than shown in Dietz's figures. They reach a length of at least 0·21 mm. and are nearly twice as long as the other cephalic spines. The specimen measured 4·9 mm. in length and was just beginning to produce ova.

Family **Dicrocoeliidae.**

Sub-Family **Dicrocoeliinae.**

Platynotrema biliosum n. g., n. sp.

(Plate VII, figs. 8–10.)

From the gall-bladder of a stone-curlew (*Burhinus grallarius*) about a dozen specimens of a large and beautiful Dicrocoeliid were obtained. A few not fully mature specimens were also obtained from the gall-bladder of a white ibis (*Ibis molucca*). It is a moderately flat species, with oval outline and pointed ends. The length is 3·3 to 4·7 mm. and the maximum breadth at the middle of the body, 1·8 to 2·2 mm. On an average the length is almost double the breadth. The cuticle is extremely thin and is studded all over with closely set scaly plates with a crescentic border much resembling reptilian scales in their somewhat irregular size and arrangement. These give the edges of the body a distinctly serrated appearance. In section these scales bear a very close resemblance to ordinary spines. Frequently they appear finely pointed; others again are blunt and irregular. They stain very deeply with haematoxylin but they readily lose the stain again.

In life the animal presents a brilliantly variegated appearance owing to the variations in the colour of the very highly developed uterus and the unusual prominence of the testes and yolk glands.

The oral sucker, which is sub-terminal and globular has a diameter of 0·55 to 0·64 mm. The ventral sucker is somewhat larger and inclined to be elongated transversely. Its longitudinal diameter is 0·7 to 0·8 mm., but the transverse diameter may approach 0·9 mm. Its average mean diameter is 0·76 mm. in a specimen 4·1 mm. long. The average diameter of the oral sucker is 0·61 mm. which gives a sucker ratio of approximately 4 : 5, but the variation is considerable. The ventral sucker is situated at a distance of 1·4 to 2·0 mm. (*i.e.* three-sevenths of the body length) from the anterior end.

The musculature of the suckers is very poorly developed as is indeed that of the body generally. In the suckers the radial fibres are very much reduced both in size and in number, while the bulk of the sucker is composed of loose spongy tissue. The sub-cuticular musculature also appears to be very feeble, the individual fibres being difficult to distinguish. The general body tissue is extremely spongy.

The pharynx is contiguous with the oral sucker and has a diameter of 0·15 mm. The short oesophagus measures 0·20 mm. in an average specimen. The intestinal diverticula diverge widely to enclose the testes and pass back between the yolk glands and the ventral sucker. About the level of the ovary they turn in towards the middle of the body but their ends are diverted outwards again. They reach to within 0·5 mm. of the posterior end, but their termination is always obscured by the uterus. Their walls are irregular in outline and there are frequent bulgings.

The excretory vesicle consists of a simple narrow sac extending forward to a short distance behind the ovary. The excretory pore is somewhat dorsal.

The genital aperture is median, a little in front of the intestinal bifurcation. The cirrus-pouch is small and slender, measuring usually about 0·5 mm. in length. It contains a proportionately large convoluted vesicula seminalis, a very small pars prostatica and a short straight ductus. There are remarkably few prostatic cells. The testes are situated symmetrically in front of the ventral sucker and closely opposed to it. Occasionally they overlap it to a slight extent. They also lie in contact with the intestinal diverticula, which they usually overlap to a greater or less extent. Their outline is extremely irregular but is not lobed. Their long diameter does not exceed 0·65 mm. and it is directed tangentially to the edge of the ventral sucker, against which the testis lies. They occupy almost the whole thickness of the body.

The ovary lies almost immediately behind the ventral sucker, a little to the left of the middle line. Its outline is also irregular but not nearly so much so as that of the testes. Its greatest diameter is about 0·27 mm. On its inner side and behind it lies a large receptaculum seminis. Laurer's canal is present. It is short and straight and opens immediately in front of the level of the receptaculum seminis. The yolk glands are entirely lateral and are almost confined to the outer side of the intestinal diverticula. They extend from the level of the anterior border of the ventral sucker to a little behind the level of the ovary. The transverse yolk ducts unite behind the ovary. The uterus is extremely highly convoluted and does not follow any very constant course. The initial convolutions, however, are usually found on the left side immediately behind the ventral sucker. Thence the course is backwards and towards the right side. A number of pale-coloured convolutions are usually seen at the right posterior end of the body.

As the uterus passes again to the left side the eggs rapidly become darker in colour so that the left posterior end of the body is usually dark brown. Passing forward it again crosses to the right and thence runs over the ventral sucker to the genital aperture. To the naked eye the posterior half of the body presents roughly the appearance of four quadrants two of which are yellow and two brown. The variations however are numerous. The convolutions are narrow and very discrete so that they do not obliterate each other, but they almost entirely hide the intestinal diverticula in the latter part of their course. One noticeable feature is the tendency to form small loops along the edges of the posterior third of the body. The eggs are excessively numerous and measure 0·024 to 0·025 × 0·015 to 0·017 mm.

Platynotrema jecoris n. sp.

(Plate VII, fig. 11.)

In the liver of the same bird (*Burhinus grallarius*) from which the foregoing species was obtained, half a dozen specimens of another form were found. At first sight they appeared to be identical with those from the gall-bladder but the more slender shape attracted attention and on closer inspection an unmistakable difference in the situation and extent of the yolk glands was at once apparent.

This second species is about the same size as the first and the length of the specimens is 2·6 to 4·8 mm. The maximum breadth, however, is only 1·0 to 1·5 mm. and it occurs somewhat further back than in *P. biliosum.* The breadth is therefore at most only a little more than one third of the length. The general outline is somewhat different from that of *P. biliosum* for the posterior end is rounded and broad and the body tapers gradually towards the head. The colouration is very much the same.

It is rather remarkable that this species, though so closely resembling *P. biliosum* in other respects, entirely lacks the cuticular scales which form so characteristic a feature of that species.

The oral sucker is usually transversely elongated but not to any great extent. The diameter varies from 0·44 mm. to 0·7 mm. and the average is about 0·56 mm. in a specimen 3·7 mm. long. The ventral sucker is difficult to measure accurately as it is much obscured by the uterus. In both these species the musculature of the suckers is feebly developed. Like the oral sucker the ventral sucker is usually transversely elongated and in one case was excessively so. The transverse

diameter measures 0·55 to 0·77 mm. and the average dimensions of the sucker as far as could be determined are 0·60 × 0·68 mm. The ratio of the mean diameters of the suckers is therefore approximately 7 : 8. The suckers are thus more nearly equal than in *P. biliosum.* The ventral sucker is situated at a distance of 1·2 to 2·1 mm (*i.e.* five-elevenths of the body length) from the anterior end, so that it is only a short distance in front of the middle of the body.

The pharynx is a small globular body situated entirely dorsal to the oral sucker and measuring 0·15 mm. in diameter. It is succeeded by a short oesophagus about 0·21 mm. long. At the bifurcation the intestinal diverticula diverge widely, passing round the outer side of the testes, thence finding their way between the yolk glands and the uterus in a sinuous course. They extend to within 0·2 mm. of the posterior end of the body. They are thus decidedly longer than in *P. biliosum.* Their walls, however, are not so much crenated. The excretory vesicle resembles that in *P. biliosum.*

The genital aperture is situated exactly at the intestinal bifurcation. The cirrus-pouch is small and slender, being only 0·35 mm. long and not reaching the level of the testes. It contains a slightly convoluted vesicula seminalis and a short prostate and ductus.

A remarkable feature of this species is the presence of a large well-defined mass of subcuticular gland-cells around the genital aperture. This mass extends from the level of the pharynx to the level of the vesicula seminalis and its breadth is about half the width of the body. The cells are closely packed together and in some places are three and four layers deep. Each cell has a fairly distinct duct leading to the cuticle. It is surprising that this structure is not present in *P. biliosum.* In the latter the usual scattered cervical glands are present in considerable numbers, but there is no tendency for them to be aggregated together.

The testes are situated immediately in front of the ventral sucker which they touch but do not overlap. They also touch the intestinal diverticula without overlapping. They measure 0·5 × 0·3 mm., their longer diameter being decidedly transverse, instead of oblique as in *P. biliosum.* They are very thick, occupying almost the whole thickness of the body, and they are overlapped by the uterus only to a slight extent. Their outline is roughly triangular and the margins are irregularly crenated.

The ovary lies immediately behind the ventral sucker a little to the left of the middle line. It is a transversely oval body, measuring

0·21 × 0·27 mm. A short distance behind and a little internal to it lies a large receptaculum seminis measuring 0·22 × 0·29 mm. The yolk glands are lateral and almost entirely external to the intestinal diverticula. They extend from the level of the middle of the ventral sucker to a distance of 0·55 mm. from the posterior end of the body. They are thus considerably more extensive than in *P. biliosum.* The transverse yolk ducts cross the body at the level of the shell gland.

The uterus is less voluminous than in *P. biliosum* and it does not obscure the intestinal diverticula to nearly the same extent. The convolutions are narrow and their arrangement displays a certain amount of symmetry. There is a large mass of light eggs lying between the receptaculum seminis and the posterior end of the body. In front of this there is a coil of loops, containing darker eggs, lying on each side of the ventral sucker and a central smaller coil lying dorsal to the sucker. This extends forwards between the testes and forms a final group of convolutions in front of the testes. This final group is almost absent in *P. biliosum.* It may be added that at no place does the uterus approach the edge of the body so closely as it does in *P. biliosum.* The numerous ova measure 0·027 to 0·030 × 0·018 to 0·020 mm.

The differences between these two species may be summed up as follows: *P. jecoris* is more slender than *P. biliosum* and has the ventral sucker placed near the centre of the body. The suckers are more nearly equal in size. The intestinal diverticula are longer and less sinuous. The genital aperture is not so far forward and the cirrus-pouch is shorter, the vesicula seminalis being much less convoluted. The testes are smaller and more transverse. The yolk glands are more extensive. The uterus is simpler and less extensive and the ova are slightly larger. In addition cuticular scales are absent and a large specialised gland is present around the genital aperture.

The genus *Platynotrema* may be defined as follows:

Dicrocoeliinae of medium size and of moderately flat broad shape and oval outline. Suckers fairly large and ventral sucker situated a short distance in front of the middle of the body. Intestine well developed; oesophagus present and diverticula long and sinuous. Genital aperture median near the intestinal bifurcation. Cirrus-pouch small and slender. Testes symmetrical, immediately in front of ventral sucker; large, irregular, crenated. Ovary immediately behind ventral sucker, small and simple. Yolk glands lateral, mainly behind the level of the ventral sucker. Uterus highly convoluted, mainly behind the ventral sucker. Ova 0·024 to 0·030 × 0·015 to 0·020 mm.

Habitat: Gall-bladder and liver of birds.

Type: *P. biliosum* Nicoll from the gall-bladder of stone-curlew (*Burhinus grallarius*), North Queensland. Type specimen T. 81. A.I.T.M. collection.

Family **Clinostomidae.**

Sub-Family **Clinostominae.**

Clinostomum hornum n. sp.

(Plate VII, fig. 12.)

A couple of specimens, only one of which was mature, were obtained from the trachea and oesophagus of a Nankeen night heron (*Nycticorax caledonicus*). Half a dozen immature specimens of what appears to be the same species were found in the oesophagus of a bittern (*Botaunus poeciloptilus*). They present a very close resemblance to *C. marginatum* (Rud.) and *C. complanatum* (Rud.) but differ from the former in possessing less voluminous yolk glands, much smaller eggs, and in having the genital aperture distinctly lateral on the right side. From *C. complanatum* they differ in having the ventral sucker nearer the middle of the body. In both these species the oral sucker is decidedly smaller than in the present species.

The length of the mature specimen is 4·6 mm. and the greatest breadth, which occurs at the level of the ventral sucker, is 1·45 mm. The breadth, however, is fairly uniform. The posterior end of the body is gently rounded; the anterior end is slightly truncated. The oral field is well developed and the oral sucker measures 0·4 mm. in diameter. The ventral sucker lies 1·2 mm. from the anterior end and has a diameter of 0·7 mm.

The walls of the intestinal diverticula are thrown into well-marked folds both on their inner and outer surfaces but there are no side branches.

The anterior testis is separated from the ventral sucker by a space of 0·7 mm. It is irregularly triangular in outline with the apex directed backwards and towards the middle line. Its greatest diameter (oblique) is 0·65 mm. A short distance behind it lies the second testis which is somewhat heart-shaped, the apex pointing backwards. It measures 0·56 × 0·63 mm.

Between the two testes on the right side, lies the small ovary. The yolk glands extend from just behind the ventral sucker to a short

distance from the tip of the tail. They leave a clear space in the middle of the body.

The small retort-shaped cirrus-pouch lies on the right of the ovary and anterior testis. It contains a comparatively large convoluted vesicula seminalis and a short pars prostatica. The genital aperture lies at the level of the anterior testis and to the right of it. The uterus contains only a few eggs which measure 0·105 to 0·11 × 0·066 mm. The opercular pole of the eggs is distinctly truncated.

MONOSTOMATA.

Family **Cyclocoelidae.**

Haematotrephus consimilis n. sp.

On two occasions a few Monostomes were found in the thoracic cavity of the spur-wing plover (*Lobivanellus lobatus*). They bear an exceedingly close resemblance to *Haematotrephus similis* Stossich, a Monostome from *Himantopus atropterus*, and are only separable from the latter species by very minor differences.

The specimens measure 10 to 12 mm. in length and about 2 mm. in maximum breadth, which occurs towards the rounded posterior end. The breadth narrows very gradually towards the anterior end. The general body colour is light yellow with two lateral stripes of a reddish colour marking the course of the intestinal diverticula.

The oral cavity is somewhat different from that in *H. similis*. It presents the appearance of a globular cup almost resembling an oral sucker. This cup is surrounded by a considerable mass of muscle fibres but there is no external limiting membrane. From this cup a short narrow prepharynx leads into a muscular pharynx of about the same size as in *H. similis*. The oesophagus is shorter than the pharynx and in some cases appears to be almost absent. The intestinal diverticula are moderately wide and run at some distance from the margins of the body.

The genital aperture is situated at the posterior border of the pharynx. The cirrus-pouch is about the same length as that of *H. similis* but is somewhat stouter. The testes and ovary are somewhat variable in size and position. In this respect they agree with *H. similis* but the testes are always smaller than in that species.

In the yolk glands the chief specific feature is to be found in so far as they extend forward to the level of the middle of the pharynx, whereas

in *H. similis* they barely reach the intestinal bifurcation. The uterus has much the same configuration as in *H. similis* and it forms the highly characteristic posterior convolutions, which almost completely surround the testes. The mature ova resemble those of the type species, but are slightly smaller. They do not exceed 0·2 × 0·08 mm. in dimensions.

Family **Notocotylidae.**

Notocotylus attenuatus (Rud.).

This parasite, which is so common in European ducks and geese, has been found here in six different birds, the green goose-teal (*Nettopus pulchellus*), the pied goose (*Anseranas semipalmata*), the black duck (*Anas superciliosa*), the stone-curlew (*Burhinus grallarius*), the spur-wing plover (*Lobivanellus lobatus*), and the black swan (*Chenopsis atrata*).

It was found first in considerable numbers in the intestine of the only pied goose I have examined, and two immature specimens were obtained from the caeca of one of two goose-teal. It is not at all common in the black duck for only a single specimen was obtained from the intestine of one bird out of nineteen.

Only a few specimens were obtained from the caeca of the stone-curlew.

REFERENCES

BRAUN, M. (1902). Die Fasciolidae der Vögel. *Zool. Jahrbücher, Abt. f. Syst.* vol. XVI.

DIETZ, E. (1910). Die Echinostomidae der Vögel. *Ibid.* vol. XII., Suppl., Part 3.

ODHNER, T. (1913). Zum natürlichen System der digenen Trematoden, VI. *Zool. Anzeig.* vol. XLII.

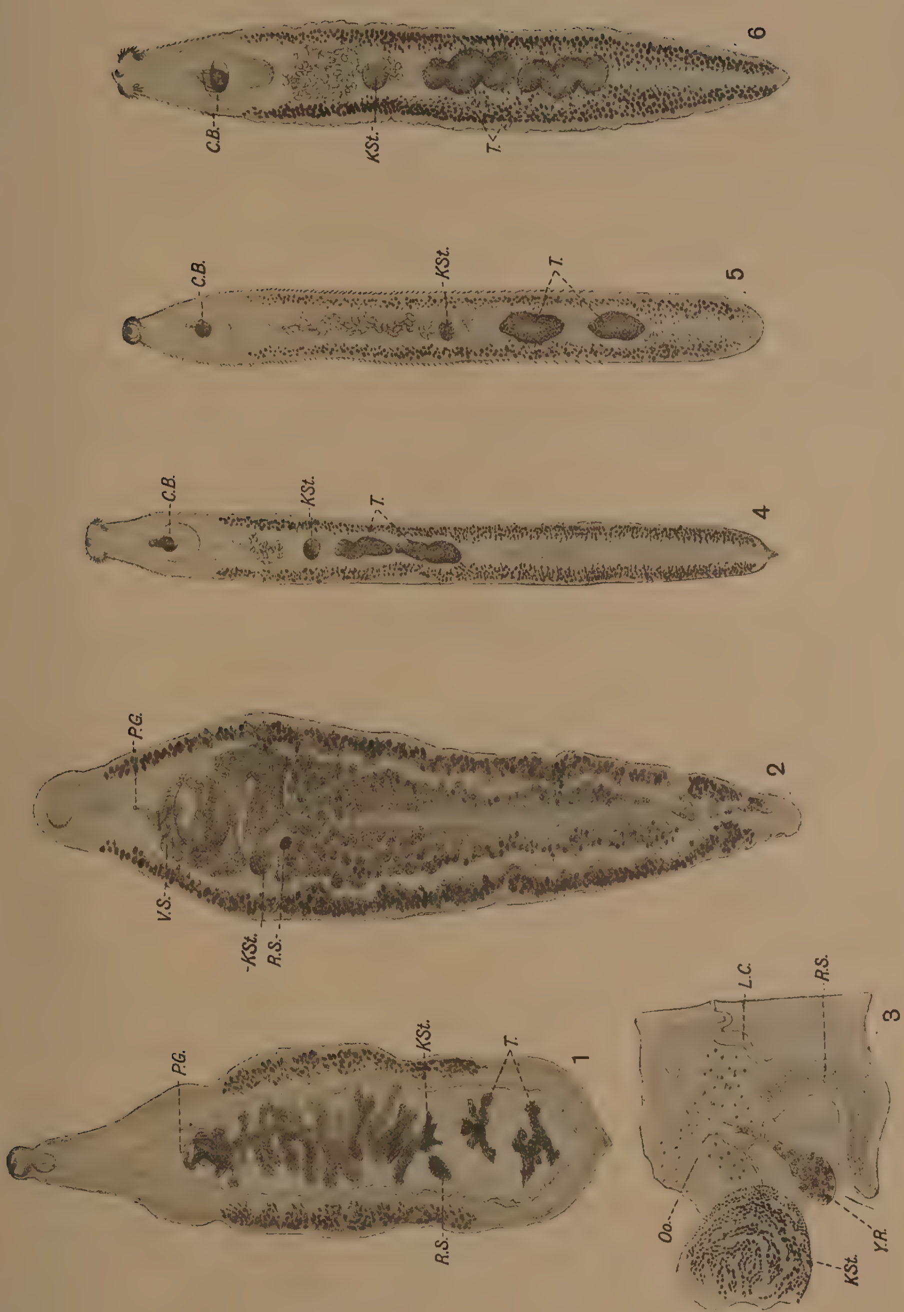
EXPLANATION OF PLATES VI AND VII.

Fig. 1. *Opisthorchis obsequens* (× 24).
Fig. 2. *Orchipedum sufflavum* (× 10).
Fig. 3. *Orchipedum sufflavum.* L.S. Shell gland complex (× 50).
Fig. 4. *Echinostomum acuticauda* (× 10).
Fig. 5. *Echinostomum emollitum* (× 17).
Fig. 6. *Echinostomum hilliferum* (× 7).
Fig. 7. *Echinochasmus prosthovitellatus* (× 40).
Fig. 8. *Platynotrema biliosum* (× 20).
Fig. 9. *Platynotrema biliosum.* L.S. Cuticle and subcuticular tissue.

Fig. 10. *Platynotrema biliosum.* T.S. Cuticle.
Fig. 11. *Platynotrema jecoris* (× 20).
Fig. 12. *Clinostomum hornum* (× 20).
Fig. 13. *Orchipedum sufflavum.* L.S. Terminal part of uterus.

The following letters apply to all the figures.

B.S. Ventral sucker.
C.B. Cirrus-pouch.
J. Intestine.
K.St. Ovary.
L.C. Laurer's Canal
Oo. Ootype.
P.G. Genital aperture.
P.P. Pars prostatica.
R.S. Receptaculum seminis.
T. Testes.
Ut. Uterus.
Vg. Vagina.
V.S. Vesicula seminalis.
Y.R. Yolk reservoir.


6
C.B.
KSt.
T.
5
C.B.
KSt.
T.
4
C.B.
KSt.
T.
2
P.G.
V.S.
KSt.
R.S.
1
P.G.
KSt.
T.
R.S.
3
L.C.
R.S.
Oo.
Y.R.
KSt.


12
P.G.
KSt.
11
C.B.
T.
KSt.
R.S
13
Ut.
J.
P.G.
P.P.
V.S.
B.S.
8
10
Vg.
R.S.
7
9
KSt.

THE OCCURRENCE OF A SLUG (*LIMAX* SP.) IN THE HUMAN STOMACH.

By C. GORDON HEWITT, D.Sc., F.R.S.C.,
Dominion Entomologist, Ottawa, Canada.

The recent note by Shipley (*Parasitology*, vi. 351–352) on the passage of a slug, *Limax marginatus* Müll., through the human digestive tract prompts me to place on record a similar case which came under my notice last summer.

On July 31, 1913, an elderly woman, Mrs G., of the city of Ottawa, on the advice of her physician brought to me a live slug measuring about 3·5 cm. in length. The specimen, which was in water, was still alive and was evidently a species of *Limax*, one of the common cream-coloured garden slugs.

Mrs G. informed me that on the previous night after retiring she had experienced uncomfortable stomachic feelings, as her food, which had been taken at irregular intervals during the day, was not being digested. In order to rid herself of the feelings of discomfort she got up and took an emetic with the result that the slug was vomited.

A careful enquiry as to her previous diet elicited the following facts. Since about a fortnight previously she had not eaten any uncooked green or other food from the garden, with the exception of a few nasturtium flowers, which could be ruled out. All her vegetable food had been well boiled and she was in the habit of thoroughly masticating her food. All possible sources of introduction were eliminated with the exception of some fresh lettuce eaten about a fortnight previously, and this appeared to be the only possible means by which the slug gained access to the stomach. In a retracted state it is conceivable that a slug would escape injury by the teeth if taken in upon such food. The comparative absence of green food and the presence of a pink colouration in the alimentary tract of the slug supported the idea that it had been in the woman's stomach for some time; but she had felt no ill effects from its presence until the previous evening.

AN EPIDEMIOLOGICAL STUDY OF FILARIASIS IN CEYLON[1].

By P. H. BAHR, M.A., M.D., D.T.M. & H. (Cantab.), M.R.C.S., L.R.C.P.

London School of Tropical Medicine.

(With 1 Map.)

My studies on the distribution of filariasis in the Fiji Islands[2] demonstrated the intimate relationship between the elephantiasis rate of a district and the microfilaria rate of the inhabitants, an observation in agreement with the previous work of Low and Daniels on the same subject. In Ceylon I resolved to again investigate this subject in order to ascertain whether in this island also a similar result could be obtained.

It is a matter of common observation in Ceylon that elephantiasis is definitely limited to certain areas, as is witnessed by the local name "Galle leg" which is applied by the European residents to this disease, though in villages but a few miles distant from the endemic area not a single case can be found. To determine, if possible, the reason of this capricious distribution, as far as time and opportunity would permit while I was engaged in investigating sprue, I examined the blood both by day and by night of a number of the inhabitants in most of the places I visited in the island. Such a survey of Ceylon was necessarily limited, but was rendered more complete by the material collected by two Ceylonese medical students, Messrs Arndt and M. de Costa, who, after being duly instructed by me, were despatched and their expenses defrayed by the Ceylon Government to such localities I myself was personally unable to visit.

[1] Based on information collected whilst investigating sprue in Ceylon, 1912–1913 and undertaken on a grant from the Ceylon Government.

[2] "Filariasis and Elephantiasis in Fiji." Supplement No. 1, *Journ. Lond. Sch. Trop. Med.* 1912, Witherby & Co.

I wish to gratefully acknowledge this generous assistance on the part of the Government authorities.

In the technique adopted of making and examining the blood films, I followed the method laid down by Manson and utilized by me in my previous work on the same subject. After dehaemoglobinization, the films were stained by haematoxylin, carbol fuchsin, and in a variety of other ways.

A total of 1824 blood specimens were taken from 1308 Sinhalese and Tamil inhabitants of Ceylon, and in 396 instances the blood was examined both by day and by night. These blood specimens were procured from 28 different towns; in many of which the situation and climatic conditions varied widely in character. In the majority of these towns 50 inhabitants were selected as a sample of the community, though in such heavily infected areas as Galle and Matara a hundred or more, mostly inmates of gaols and hospitals, were procurable. On account of the innate native modesty which prevented the women coming forward to have their blood examined, it was difficult to maintain an equal proportion of both sexes, and consequently the males outnumbered the females by three to one.

Microfilariae were found in the blood in 43 people, or 2·3 %.

Periodicity. These microfilariae exhibited marked nocturnal periodicity; in one case only were they found sparingly (one in a blood smear) during the daytime.

Morphology. Though no adult worms were procured, yet from their nocturnal periodicity and the minute morphology of the embryos there could be little doubt of the identity of the Ceylon filaria worm with *Filaria bancrofti.*

Age and Sex. 4·1 % of the males were found infected against 0·8 % of the females, a proportion which bears out the generally accepted liability of the former sex to filariasis. The youngest male harbouring microfilariae was a boy of eight years old, the youngest female a young woman of twenty-five.

Filarial Diseases. Forty-seven cases of elephantiasis were seen and examined; only two of these, or 4·2·%, harboured microfilariae in their blood. The legs were most commonly affected, but in comparison with the former an elephantoid disease of the upper extremities was rare. Of the total number of cases seen, elephantiasis of the arms was noted twice, of both arms and legs four times, of one leg 28 times, and of both legs 13 times. The males were most commonly affected with elephantiasis, 39 cases occurred in men, only eight in women. The

rarity of a similar affection of the scrotum is a remarkable point, and in the female only one case of elephantiasis of the vulva with implication of both legs also was noted. Many of the cases bore scars of filarial abscesses in the groin, also marks of a previous yaws infection.

Seven cases of hydrocele of suspected filarial origin, but unassociated with elephantiasis of the scrotum, and one case only of lymph scrotum associated with varicose groin glands, but without any microfilariae in the blood, were seen.

I only encountered two cases of chyluria, both harbouring microfilariae in their blood. The absence of any palpable enlargement of lymphatic glands in cases with other signs of filarial disease, such as elephantiasis, was a noticeable feature, especially when contrasted with the enlargement of these glands which I found almost invariably in filariated Fijians.

In subjects with no obvious signs of filarial disease I found an enlargement of the epitrochlear or of the inguinal glands in 3·1 %, and of the natives affected in this manner only three, or 7·5 %, had microfilariae in their blood.

Distribution of filariasis in Ceylon.

A glance at the map which accompanies this paper will convince the reader that wherever the microfilaria rate is a high one, there also I found a higher proportion of elephantiasis cases than elsewhere. This statement is only proportionally true; for example, the microfilaria rate—14·2 %—for a certain village—Ambalantota in the Southern Province—is a relatively high one, though only three cases of elephantiasis were seen in that locality.

The absence of filariasis in the cool up-country districts such as Avisawella, Badulla, Nuwara Eliya and Kandy, is easily explicable by the relatively small numbers of mosquitoes capable of acting as definitive hosts in these localities, and by the comparatively low mean average temperatures such as would effectually prevent the development of the filaria at these higher elevations.

This explanation, however, does not apply to the hot low-lying swampy areas of the Southern and Eastern Provinces, and especially to the villages of Topur and Muttur, near Trincomalee in the Eastern Province, and separated by a distance of but ten miles from each other. (See Map.)


MAP
shewing distribution of
FILARIASIS IN CEYLON.
The figures inside the circles denote the percentage of inhabitants harbouring microfilariae in their blood. The black lines inside the circles denote approximately the number of cases of elephantiasis in each district.
80°
81°
9°
8°
7°
6°
81°
80·5°
80°
79°
75°
70°
60°
1·5 JAFFNA
Mullaittivu
N. P.
0 Vavuniya
0 Trincomalee
0 Muttur
Topur
0 ANURHADHAPURA
N. C. P.
Puttalam 0
N. W. P.
Chilaw 0
Hiripitya 4
1·9 KURUNEGALA
C. P.
0 KANDY
E. P.
2·3 BATTICALOA
Negombo 0
COLOMBO
0 Avisawella
0 Nuwara Eliya
0 BADULLA
U. V. A.
W. P.
0 RATNAPURA
S. A. B.
Kalutara 0
Induruwa 11·1
Ambalangoda 0
S. P.
Illekmulle 1·8
Hakmana 0
14·2
2 Hambantota
Ambalantota
8·8
Tangalla
GALLE 4·7
0 Weligama
4·1 Matara
Isothermal Lines

I collected the mosquitoes wherever I was able and I give at the end of this paper a list of localities in which different species were taken. Two species, *Culex fatigans*, and more especially *Mansonioides uniformis*, were abundant in all filaria-infected areas. I am inclined to regard the latter, relying solely on epidemiological grounds, as being the main filaria carrier in Ceylon, a subject worthy of further investigation.

The few transmission experiments which I made with different anophelines, especially *M. barbirostris*, proved negative.

The relation of malaria to filarial disease.

I saw three cases of elephantiasis in a community heavily infected with malaria and of whom 44 % had enlarged spleens and 22 % malaria parasites in their blood, and 1·8 % microfilariae. In the neighbouring town of Tangalla the microfilaria rate was found to be 8·8 %, the spleen rate nearly 99 %, and the parasite rate (mostly malignant crescents) to be 25 %. Arguing from these two instances there is no epidemiological evidence in favour of a supposition that the one infection militates against the other, or that the locally prevalent anopheline is incapable of transmitting both the malaria parasite and the filaria worm at the same time.

Finally I submit that this investigation has shown

(1) That of the four or five known species of filaria blood worms, only one of them, viz. *F. bancrofti*, is represented in Ceylon.

(2) That its periodicity, as in the case with India, the West Indies and many other countries (but not in many of the Pacific Islands), is of a definitely nocturnal character.

(3) That it is a rare parasite in the north and centre of the island, but a common one on the east and south coasts.

(4) That in the endemic areas, the topographical distribution is apparently of a most capricious character.

(5) That, whereas in some of the villages at least 26 % of the adults are infected, in the neighbouring villages the inhabitants are quite free from the parasite and its associated diseases.

This latter circumstance suggests careful investigations into an apparent anomaly, for could an explanation of the liability to the parasite of one village community and the immunity of a neighbouring village be supplied, we might be placed in possession of knowledge which would enable us to control or eradicate a serious disease agency. Further, such an investigation might lead to or suggest an explanation

of a similar anomaly which is known to exist in another mosquito-conveyed, but far more serious infection, malaria.

I would suggest that a small commission, say of two members, be sent to one of these ascertained filarial centres, that they be instructed to work out radially from these centres, tracing by systematic examination of the blood of the inhabitants the presumed gradual diminution and final disappearance of filarial infection from the district, at the same time a study of the mosquito fauna of the region and their topographical distribution be ascertained, and their efficiency as filarial carriers be determined.

It may be that the mosquito carrier is widely distributed. If this should turn out to be the case, further investigation and experiment might show why it is efficient in one place and inefficient in another. If the mosquito carrier be limited to special villages, the reason for this should be ascertained.

I can foresee in the successful prosecution of such investigations the acquisition of important additions to tropical pathology, and it may be valuable indications for the prevention of filariasis, and possibly of other mosquito-borne diseases.

A list of Mosquitoes collected in Ceylon and kindly identified for me by Col. Alcock, C.I.E., F.R.S. The letters N.P., S.P., etc. refer to the Northern or Southern Province, etc.

Species.	*Localities.*
Anophelines.	
Myzomyia rossi Giles.	Badulla (2200 ft.); Nuwara Eliya (6300 ft.); Kurunegala (320 ft.); Batticaloa (sea-level).
„ *albirostris* Theob.	Kurunegala.
„ *culicifacies* Giles.	Kurunegala and Badulla.
„ *punctulata* Dönitz.	„ „
Myzorhynchus sinensis Wied.	„ „
„ *barbirostris* v. d. Wulp.	„ „
Nyssorhynchus fuliginosus Giles.	„
„ *jamesi* Theob.	„
„ *maculatus* Theob.	Kurunegala and Nuwara Eliya.
Anopheles gigas var. *refutans*, sp. nov. Alcock.	Nuwara Eliya.
Culicines.	
Culex concolor	Kurunegala and Colombo (sea-level).
„ *gelidus*	Tangalla (S.P.), and Colombo.
„ *mimeticus*	Nuwara Eliya and Kurunegala.

Species.	*Localities.*
Culicines (continued).	
Culex fatigans	Badulla, Kurunegala, Tangalla, and Nuwara Eliya.
„ *vishnui*	Weligama (S.P.), Muttur (E.P.), Tangalla and Badulla.
„ *fuscocephala* ..	Tangalla, Badulla and Nuwara Eliya.
Culicomyia ceylonica ..	Badulla and Nuwara Eliya.
Ochlerotatus pallidostriatus ..	Tissa (S.P.) and Kurunegala.
„ *stenoetrus* ..	Weligama (S.P.).
Desvoidya obturbans	Anurhadhapura (N.W.P.) and Kurunegala.
Mansonioides uniformis ..	Kanthalai (E.P.), Chilaw (N.W.P.), Talawa (N.P.) Tissa, Weligama, Hakmana and Illekmulle (S.P.).
„ *annulifer* ..	Tissa (S.P.).
Aedes mediofasciatus ..	Matara (S.P.).
Stegomyia scutellaris ..	Peradeniya (C.P.).
„ *sugens*	„
„ *trilineata* ..	Ramboda, 5000 ft. (C.P.).
„ *fasciata*	Colombo.

STUDIES ON MALARIA IN CEYLON. WITH SPECIAL REFERENCE TO ITS PREVENTION IN AGRICULTURAL DISTRICTS[1].

By P. H. BAHR, M.A., M.D., D.T.M. & H. (Cantab.), M.R.C.S., L.R.C.P.

London School of Tropical Medicine.

(With Plates VIII–XIII and 2 Maps.)

For the purpose of present study, Ceylon may be regarded as presenting two definite climatic zones—the hot low plains and the damp cool tea-bearing area of the central provinces, a district lying between the isothermal lines of 70–75° F. (*vide* map 1); these two zones are probably the main factors in influencing the distribution of malaria in the island.

Malaria is *par excellence* a scourge of the low-country, which may again be divided for our present purpose into the hot damp agricultural districts of the Western and Southern, and the hot but dry jungles of the North and Eastern Provinces.

I have been unable in Ceylon, in contradistinction to what we know of the endemic malaria of the Malay States and of the Himalayas, to obtain any evidence of fresh infections arising at an elevation above 2200 ft., though it is said that epidemics have occurred in former times at an elevation considerably higher than this in certain narrow and confined valleys near Kandy. In the Tamil coolies employed on the tea plantations, relapses of an infection acquired originally in India or in Ceylon at a lower elevation may occur, especially during the south-east Monsoon, but malaria *per se* cannot be regarded as affecting in any way the salubrity of the upcountry tea estates. It is otherwise on the rubber plantations of the Western Province and in the rice

[1] Based on information collected whilst investigating sprue for the Ceylon Government. 1912–1913.

growing and cocoanut bearing districts scattered throughout the low country.

In the jungles of the North-Central and Eastern Provinces malaria has been held responsible for the present depopulation of certain districts and the abandonment of the great cities of Anurhadhapura and Polonnurrua, formerly the seats of the ancient Sinhalese kings, and where in former times hundreds of gigantic tanks, since fallen into disrepair, were constructed, and water for the irrigation of the rice fields stored. Latterly many of these have been restored by the Government, but so far, however, probably on account of the prevalence of the endemic malaria, it has been found difficult to induce any natives to take up the cultivation of the adjacent rice-fields.

I have studied malaria in detail in three areas in Ceylon, namely, Kurunegala in the North-Western, Badulla in Uva, and Tangalla in the Southern Provinces. On the west coast it has been studied in detail by Major S. P. James at Talaimannar, the Ceylon terminus of the new railway to India.

The variety of malaria parasite found.

Blood films were taken from 539 natives, a quarter of an hour being allotted to the examination of each slide. The parasite rate was found to be 14·4 %; in the majority of cases the infection of malaria parasites was a small one, only a single gamete or ring-form being found in the whole film.

The quartan parasite greatly predominated and formed 63·8 %, the benign tertian 19·2 %, and the subtertian 17 %, of the total number examined. Double infections were found only five times as follows:

Tertian and quartan twice.
Quartan and subtertian once.
Tertian and subtertian once.
Quartan, tertian and subtertian once.

Crescents, or gametocytes, were found eight times out of fourteen subtertian infections, an abnormally high proportion when contrasted with the small number found by Plehn and others in this infection in Africa. A similar preponderance of the quartan parasite was found by Christophers (*Sci. Mem. Govt. India*, 1912, New Series, No. 56) in his recent work in the Andamans, a fact he wishes to attribute to the proneness of the infection to relapse and to the relatively small number of gametocytes produced by the quartan, as compared with other forms of the malaria parasite.

The Ceylon anopheline mosquitoes.

The following is a list of anopheline mosquitoes I collected in Ceylon, identified by Col. Alcock, C.I.E., F.R.S., and Major S. P. James, I.M.S.

Anopheles (*Myzomyia*) *rossii* Giles.
,, ,, *culicifacies* Giles.
,, ,, *albirostris* Theob.
,, ,, *punctulata* Donitz.
,, ,, *listoni* Liston.
,, (*Myzorhynchus*) *sinensis* Wied.
,, ,, *barbirostris* v. d. Wulp.
,, (*Nyssorhynchus*) *fuliginosus* Giles.
,, ,, *jamesi* Theob.
,, ,, *maculatus* Theob.
,, *gigas* var. *refutans*, sp. nov. Alcock.

(*Refutans* is similar to *gigas* except for three or four very narrow light tawny bands on the palps one of which is situated at the tip.)

Of these no less than six species have been recognized as malaria carriers in other parts of the tropics, but so far only one, *M. culicifacies*, has definitely been proved—by Major James in Talaimannar—to be the natural carrier of infection in Ceylon.

Anopheles gigas var. *refutans* was only found breeding at an elevation of 6000 ft.; even in Nuwara Eliya it was a scarce species, and hardly ever entered the houses or showed any proclivity to feed on human blood. Only two other species of *Anopheles*, *M. rossii* and *N. maculatus*, were found breeding in the swift streams at that altitude; the latter species, although a recognized carrier in Malaya, appears to play little part in the spread of malaria in Ceylon; it is possible that the temperature encountered in its breeding areas is too low to permit of the complete developmental cycle of the parasite in this definitive host to take place.

M. culicifacies is generally conceded by Christophers and James to be the main natural malaria-carrier in India, and has also been found naturally infected by the latter in Ceylon.

M. albirostris has been found naturally infected with zygotes both in India and the Malay States.

M. listoni has been found naturally infected in India and is capable of transmitting malaria in captivity.

M. sinensis is recognized as a carrier of the benign tertian parasite by Tzuzuki in Japan, and has been found infected with zygotes by Stanton on two occasions.

M. fuliginosus has been found naturally infected in India by J. R. Adie, and in Malaya by Stanton.

N. maculatus has been found infected in nature in Malaya by Malcolm Watson, and under experimental conditions by Stanton. The former has associated its presence with severe malaria in the hill country.

Attempts were made in Kurunegala to transmit the quartan parasite through *Myzorhynchus barbirostris*, by far the most abundant species of anopheline, without success. Great difficulty was experienced in finding a suitable case of infection and in inducing the native to submit to mosquito bites at night time.

Malaria in Kurunegala.

Malaria was studied in greatest detail in Kurunegala. This town, 381 feet above sea-level, is the capital of the North-Western Province, and the centre of an important agricultural district mainly devoted to the cultivation of cocoanuts ; it is also an important labour distributing centre to districts which have been considerably opened up during the last 20 years. It is situated 58 miles by rail from Colombo and is the residential centre of the local staff of the Northern line.

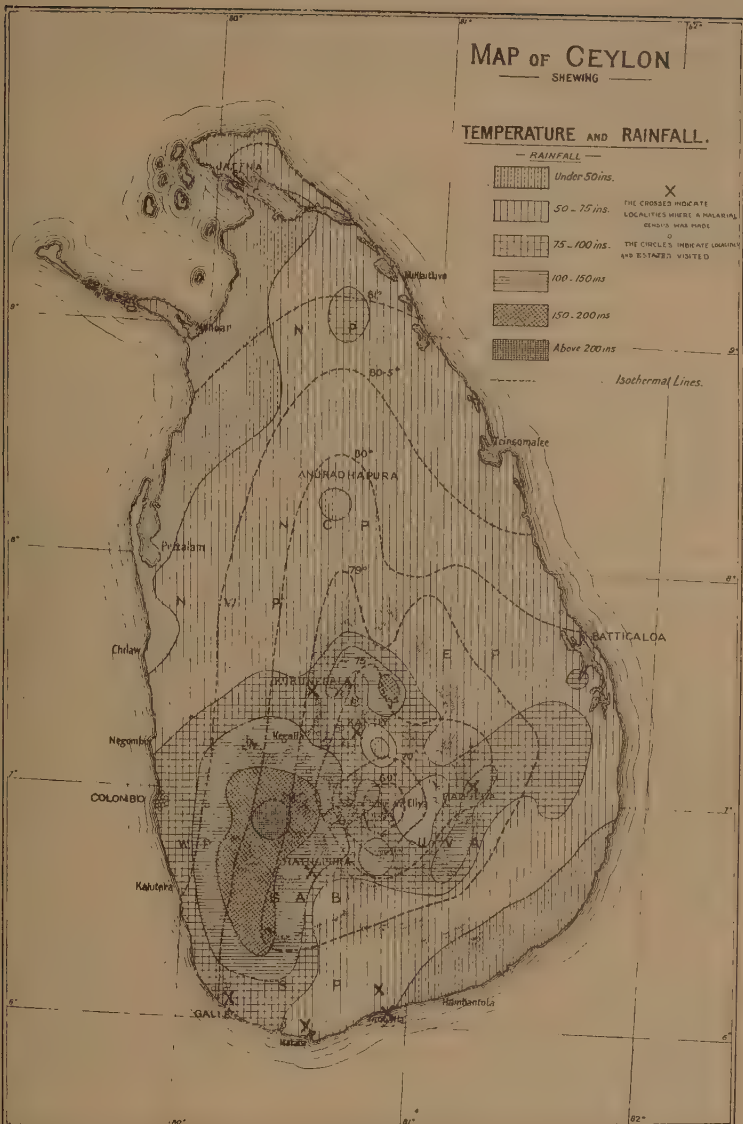
According to the 1911 census there is within the limits of the town, which occupies an area of over four square miles, a population of 8100.

Within these limits also there are over 500 acres of paddy or rice fields, but only 300 of these are of importance for our present purpose, as the remainder are cut off by a series of bare rocks (*vide* Map 2) which arise abruptly towards the north-east of the town, and may on that account be disregarded as having any influence on the spread of the malaria in the town proper.

The town consists of a number of residential houses and a bazaar of about 15 acres in extent occupied by ill-kept straggling boutiques or small shops. The houses of the better classes are scattered along the main roads and converge on the bazaar.

Towards the north of the town there is a tank of some ten acres in extent which is used for irrigation purposes and to a limited extent for bathing and drinking. A water course emerging from this supplies the adjacent paddy fields and eventually joins a stream called the Boo Ela ; this latter has its source in another large tank named the " Wenaruwewa " situated a mile beyond the southern town limits.

The inhabitants of Kurunegala can be divided into four social classes, (1) the Government servants employed in the Government offices and


MAP OF CEYLON
SHEWING
TEMPERATURE AND RAINFALL.
RAINFALL
Under 50ins.
50 - 75 ins.
75 - 100 ins.
100 - 150 ins
150 - 200 ins
Above 200 ins
Isothermal Lines.
THE CROSSES INDICATE LOCALITIES WHERE A MALARIAL CENSUS WAS MADE
THE CIRCLES INDICATE LOCALITIES AND ESTATES VISITED
JAFFNA
Mullaittivu
Mannar
Trincomalee
ANURADHAPURA
Puttalam
Chilaw
BATTICALOA
KURUNEGALA
Negombo
COLOMBO
Kalutara
GALLE
Hambantota
N. P.
N. C. P.
N. W. P.
E. P.
W. P.
U. V. A.
S. A. B.
S. P.
80·5°
80°
79°
75°
70°
60°

Map 1.

on the railway, (2) the boutique or small shop keepers, (3) villagers or "goiyas," perennially engaged in tilling and irrigating the rice fields, and (4) colonies of Tamil oilmongers engaged in extracting cocoanut oil from copra.

Climate.

The annual rainfall is 80·5 inches, the wettest months are April, May, October and November; the average mean temperature is 78·8° F. about equal to that of Colombo.

Malaria in Kurunegala.

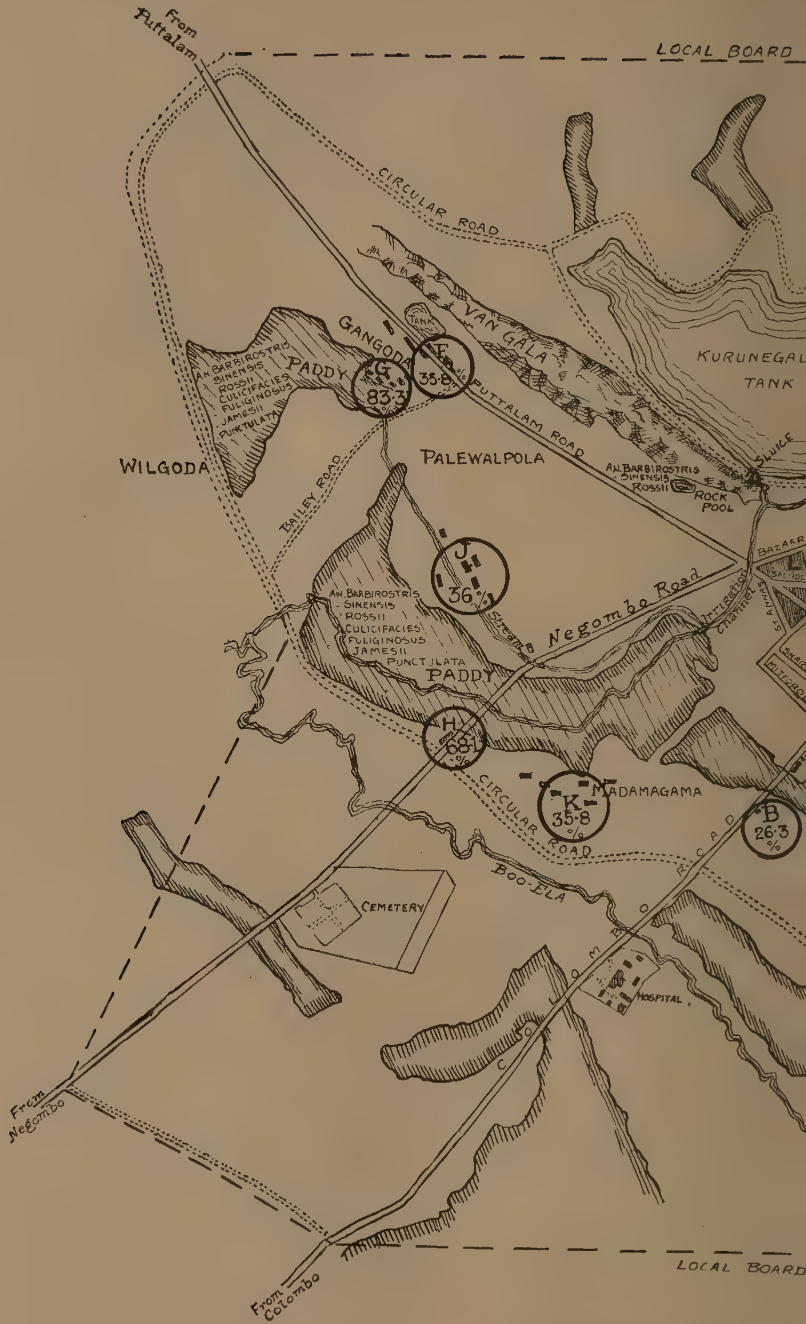
I am much indebted to Dr S. T. Gunasekara, who has been resident for one and a half years in the town, and who has made a most extensive study of the subject, for many facts regarding the epidemiology and incidence of this disease, and which he has incorporated in a report recently issued (Ceylon, 1913, XXXVII).

The town of Kurunegala (pronounced Cornygalle) has always borne a bad reputation for malaria, as witnessed by the term "Kurunegala fever" by which malaria is popularly known throughout Ceylon. From time to time it has assumed epidemic proportions in the town and has been a source of serious loss to the Government and to the planting industry. According to the records compiled by Gunasekara the epidemics have generally occurred after a season of moderate rainfall followed by prolonged drought; such a drought is apt to favour the propagation of malaria, firstly by drying up all the natural pools in the town and thereby killing off the larvivorous fish, thus affording suitable breeding places for anophelines after the rains where they can breed undisturbed, and secondly by the hardships which such a drought entails and which predispose the poorer natives to relapses of a previous infection.

There are as a rule two malaria seasons in Kurunegala every twelve months, each following the Monsoon rains. For the eight years, 1904–1911, Gunasekara has constructed a chart showing the incidence of malaria in the district, and from which he has been able to arrive at several important conclusions as regards the epidemiology of the disease in the Kurunegala district.

The main points are as follows:

(1) In the years 1906, 1908 and 1911 malaria assumed epidemic proportions.



Map 2. Map of Kuruneg
breedin
Total

ng distribution of malaria and
of Anopheles.
sq. miles.

(2) The fastigia of temperature and of rainfall generally coincide; the curve of malaria incidence commences to rise after the fastigium of climatic influences and reaches its maximum in three or four months.

(3) There are generally two rises in the malaria incidence during the year; of which the one occurring during August, September, and October is generally the highest.

Mortality from malaria.

The average annual death-rate from malaria is about 109 per annum, or 1·3 %, but in 1911 it rose to 175 per annum, or 2·1 %. Not only has malaria been directly responsible for this large number of deaths, but it has also been the source of serious inefficiency and direct loss to the Government in other ways. From the statistics Gunasekara compiled it appears that normally considerably over 22 % of the Government officers in Kurunegala are annually incapacitated from service on account of fever.

Anti-malarial measures so far adopted in Kurunegala.

The anti-malarial measures instituted under the guidance of Dr Gunasekara have been designed to improve the general sanitation of the town and to prepare the masses for a still more extensive campaign. These have consisted in, (*a*) education of the public in malarial prophylaxis by means of lectures, (*b*) general sanitary measures, (*c*) daily quinine distribution, (*d*) mosquito reduction by gangs of coolies clearing drains, filling in hollows, etc., (*e*) screening hospital wards, Government bungalows, etc.

Though all these measures have been conscientiously carried out for the last one and a half years, it was realised that the amount of malaria had not been apparently reduced. For political and economic reasons no steps had been taken to abolish the paddy fields in the centre of the town as it had been deemed advisable to observe the part these fields played in the spread of the malaria.

At the request of the Hon. the Colonial Secretary of Ceylon, I spent a week in February and March, 1913, in Kurunegala studying this question; the main results of this enquiry are embodied in the present report.

435 blood slides were taken and microscopically examined. I wish to express my indebtedness to Sir Patrick Manson for the interest he has taken in the progress of the work, and for his invaluable assistance in the tedious task of examining the blood slides.

I have also received considerable assistance from Major S. P. James. He has confirmed, and in many cases corrected, my diagnosis of the local anopheline mosquitoes.

In considering this report it must be borne in mind that the weather was abnormally dry at the time of my visit, consequently the paddy fields lay fallow; there were very few mosquitoes and little, if any, actual fever. The results, however, may be considered of some scientific value as indicating the condition of affairs when the town is free from epidemic malaria.

I wish to express to Dr S. P. Gunasekara my gratitude for the assistance he has afforded me in this enquiry.

The local anopheline mosquitoes.

The main species of anopheline mosquitoes found by me in Kurunegala, in order of their frequency, are as follows:

(1) *Myzorhynchus barbirostris.*
(2) *Myzomyia rossii.*
(3) *Myzorhynchus sinensis.*
(4) *Myzomyia culicifacies.*
(5) *Myzorhynchus fuliginosus.*
(6) *Myzorhynchus jamesi.*
(7) *Myzomyia punctulata,* an uncommon species in Kurunegala.
(8) *Myzomyia albirostris,* only three or four specimens were bred from larvae collected in the paddy fields.
(9) *Nyssorhynchus maculatus,* a rare species in Kurunegala, bred from larvae obtained in a swift-flowing stream behind the Government Agent's house.
(10) *Myzomyia listoni,* only one specimen obtained.

Thus, out of ten species of *Anopheles* found in Kurunegala, six have been proved elsewhere, mostly in Malaya and in India, to be conveyers of malaria. Of the known malaria carriers, *Myzomyia culicifacies* was by far the most abundant species.

Adult anopheline mosquitoes have been found in houses in Kurunegala and in various bungalows in the town during the daytime by Gunasekara They were mostly specimens of *M. barbirostris* and *M. sinensis.* The railway station bungalows, where malaria is so prevalent, have often been searched by Gunasekara, without result.

Fig. 1. Kurunegala Tank. Numerous larvivorous fish, but no anopheline larvae.

Fig. 2. Rock Pool. A rainwater pool in the Quarry. Breeding place of *M. barbirostris*, *M. sinensis*, and *M. rossii*.

This he attributes to the amount of uncleared jungle in the vicinity, into which the anophelines retire during the daytime. I failed to find any anophelines in the houses of Habage village (Appendix II A) during an extensive search in the daytime.

The areas in which these anophelines breed.

For this purpose we have to consider the main sheets of water found in Kurunegala town. I propose to say a few words about each area in turn.

(1) *Paddy Fields;* within the town limits these extend over an area of about 300 acres. The majority of these fields act as breeding grounds of mosquitoes only at certain seasons of the year when they are flooded, and more especially, according to Gunasekara's observations, when the water is subsiding and leaving small isolated pools behind. Certain fields supplied by the town wells and by the irrigation channel from Wenaruwewa tank (*vide* Pl. X, fig. 5) are, however, nearly always more or less under water. By reference to the map it will be seen that the paddy fields in the town are supplied with water from two main sources. The block on the Negombo road is supplied from the Kurunegala tank by an irrigation channel eventually joining the Boo Ela; the other two blocks, one on the Colombo road, the other near the railway station, are supplied by an irrigation channel from the Wenaruwewa tank, situated one mile without the town limits. Water is supplied from this tank twice weekly, or whenever possible, mainly for filling the locomotive sump at the railway station, with which it is connected.

According to Gunasekara's observations these permanently flooded fields act as a constant breeding ground of anophelines all the year round.

(2) *Tanks.* There are two tanks to be considered, the main tank and a bathing tank (*vide* Pl. X, fig. 4), on the Puttalam road; both are stocked with fish. No larvae have ever been found in either, so they may be dismissed as factors in the situation.

(3) *Irrigation Channels.* When properly graded and when the water is flowing fast, little danger is to be expected from this source. The natives, however, are in the habit of partially damming up these channels in order to catch fish, thus creating stagnant pools, in which anophelines breed. This practice should be forbidden. The side channels leading off from the main channels are also a source of danger. These are so graded that the water has gradually to well up from below in

order to fill them, and thus cannot flow by force of gravity alone. On subsiding, the water leaves stagnant pools behind, in which larvae are to be found. This is especially so in the case of the channel situated behind the station (*vide* Pl. XI, fig. 7).

(4) *Rock Pool* (Pl. VIII, fig. 2). This is a rainwater pool, which has collected in a disused quarry. Great numbers of larvae can nearly always be found there, though their numbers have been somewhat lessened by the introduction of fish by Gunasekara.

(5) *Borrow Pits* (Pl. XIII, fig. 11). Many of these have been excavated by the Public Works Department during their work on the Circular Road in the south of the town; formerly they used to be fertile breeding grounds of anophelines. The majority have been dealt with under Gunasekara's directions; as a focus of malarial infection they may now be almost disregarded.

(6) *Freshwater Wells.* According to Gunasekara there are 180 town wells; in only 18 of these were a few larvae found. Larvivorous fish have now been introduced, so that as centres of infection they, too, may be disregarded. One well supplies some blocks of paddy fields on the Rajaphilla road; these are nearly always under water, and larvae can always be found there (Pl. X, fig. 5).

(7) *Rock Stream* (Pl. IX, fig. 3). This stream flows behind the Government Agent's residence; in the dry season it is represented by a series of stagnant pools. From larvae captured there, *M. barbirostris* and one specimen of *M. maculatus* (*vel wilmori*) have been bred. Reference must here be made to a practice of the villagers of damming up this stream to form a bath for their bulls, thus creating large stagnant pools; this practice also ought to be forbidden.

(8) *Water Channels on each side of Railway Cutting* (Pl. XII, fig. 8). This water supplies the engines at the station. The courses are only cemented underneath the bridge, and *are not kept clean*; the result is that they are overgrown with slimy water plants (*spirogyra*), which form an excellent feeding ground for larvae, and to which they adhere by their tails. This stream, and the presence of continually flooded paddy fields in the vicinity, probably account for much of the malaria amongst the railway staff for which the station at Kurunegala has an invidious reputation. There is no reason why this reproach to the Railway Department should not be removed, and *increased* efficiency result. The following list will give an idea of the importance of these various sheets of water in breeding malaria-conveying anophelines. Malaria carriers are printed in heavy type:

Fig. 3. Rock Stream. A swift stream flowing behind the Government Agent's residence. Breeding place of *M. barbirostris*, *M. rossii*, and *M. maculatus*, showing method of blocking stream to wash cattle.

	Nature of Breeding Ground		
	Paddy Fields	Rock Pool	Railway Cutting
M. barbirostris ..	19	47	—
M. rossii	26	42	14
M. sinensis	15	7	—
M. culicifacies ..	3	—	7
M. fuliginosus ..	1	—	—
M. jamesi	2	—	—
M. punctulata ..	1	—	—
Total examined	67	96	21

The water from these various areas containing larvae was placed in separate cages, as has already been related. Each mosquito hatched was identified.

From this table it will be readily gathered that a greater variety and higher proportion of malaria-conveying anophelines have been bred from paddy fields than from elsewhere. In this connection I must consider shortly the natural enemies of the mosquito larvae in the paddy fields. These are:

(1) *Larvivorous fish;* of these four varieties are found, three of which are surface feeders, as follows:

(*a*) "Pathia" (*Barbus stigma*), a most efficient larvivore;
(*b*) "Dandie" (*Rasbora lanicornius*);
(*c*) "Sudaya" (*Danio malabaricus*);
(*d*) "Ahirawa" (*Lepidociphalicthys thermalis*), a bottom feeding fish.

These species are found in all paddy fields when in flood. In the first instance, they escape from the tanks and are carried to the fields by the irrigation channels; it is thought, however, that a certain number are carried to remote blocks as spawn on the feet of water birds. As far as is known, they all multiply in the paddy fields, provided that there is sufficient water. Gunasekara has made numerous observations on their larvivorous propensities. It appears that these species will only feed on live larvae. Many of the anopheline larvae have in consequence adopted the habit of shamming death, and many doubtlessly escape by this means. It is a fallacy to think, however, that whenever these fish are found in paddy fields no larvae can be found at the same time. *This is not so.* There are several explanations of this fact:

(*a*) Larvae are generally found in the "seepage" water which has filtered through the bunds, leaving the fish behind.

(*b*) In the larger pools which form in the paddy fields the larvae are found at the edges of the pools, while the fish keep the centre.

(*c*) Holes formed by the feet of cattle (*vide* Pl. XI, fig. 6), and into which the fish are not able to enter, are ideal breeding places, and in these Anopheline larvae are invariably found.

Frogs abound in all streams and paddy fields, but they do not appear to feed on larvae at all.

(2) *Larvivorous larvae.* The commonest larvae with cannibalistic proclivities are the large Culicine larvae of *Culex concolor*, a common and voracious mosquito often found in the roofs of native houses. These larvae are frequently met with in paddy field water.

The effect of these areas on the prevalence of local malaria.

Adopting the plan which has been utilized, whenever malaria has been adequately studied, I have taken the degree of infection of children under fourteen years of age as an index of the general population.

To determine which of the breeding grounds is the main focus of infection, two courses are open—one, to determine the evidences of past; the other, of present malarial infection—

(1) By taking the splenic index.
(2) By microscopical examination of the blood.

(1) *Splenic Index of the Children.* 435 children have been examined by abdominal palpation to determine the percentage with enlarged spleens (Appendix I). These children have been selected in batches, bred and born in certain areas of the town. As far as was possible every child in Kurunegala was examined. The total spleen rate was found to be 34·7 per cent., and was higher in males than in females. In the male sex the highest index was found to be reached by the tenth, in the female by the twelfth year (Appendix I).

A cursory glance at the map will convince the reader that the incidence of malaria, as judged by the spleen rate, varies considerably in various parts of the town; detailed statistics on this point are given in Appendix II. The letters A, B, C, etc. on Map 2 refer to different collections of houses where these observations were made.

The conclusions I arrived at from this study are that, wherever the houses are crowded together in the *vicinity of paddy fields*, there the spleen rate is a high one, irrespective of the social status of the inhabitants or of the sanitary conditions under which they are living. There are one or two areas to which I would call attention.

Fig. 4. Bathing Tank. Tamil Oilmongers' quarters, Puttalam Road. Numerous larvivorous fish. No anopheline larvae.

Fig. 5. Permanently Flooded Paddy Fields. (On the Rajaphilla Road.) These fields are supplied by well water and constitute a permanent breeding ground of anophelines.

In the area marked H, although the children are of a good social status, well fed, and well cared for, the spleen rate is high—68·1 per cent. These houses are built upon the Bund of a paddy field (Pl. XII, fig. 9).

A and K are similarly situated areas, the inhabitants are of the same class (" goiyas "), but the houses are scattered, and consequently there is less chance of the conveyance of infection ; the spleen rate is here a lower one.

The absence of any evidences of malaria at C is easily explicable. A small number of children only could be examined ; these had but recently, being the families of the police, arrived in the district.

The areas marked F and G respectively next call for a few comments. G is a village inhabited by Sinhalese " goiyas," in close proximity to paddy fields, which, being naturally marshy ground, are nearly always flooded. The spleen rate, 83·3 per cent., is the highest encountered in Kurunegala, yet this village is separated only by a small belt of cocoanut and areca palms from the miserable and insanitary quarters of the Tamil oilmongers (F, Pl. XIII, fig. 10) ; these latter quarters adjoin a bathing tank (Pl. X, fig. 4), which, on account of the number of fish which inhabit it, does not serve as a breeding area of anophelines.

At F the splenic index is less than half of that at G. The explanation of this fact would appear to be that the belt of trees I have already mentioned serves to screen off to some extent the mosquitoes bred in the paddy fields at G. It must be conceded that there is a great disparity between the prevalence of malaria amongst the children bred in the vicinity of these paddy fields and amongst the ill-kept denizens of the bazaar (L), where the spleen rate is but 7·1 per cent. These facts, together with those already related, are to my mind sufficient to condemn the paddy fields as constituting the main foci of malarial infection in Kurunegala.

(2) *Microscopic Examination of the Blood.* The blood of all these 435 children was systematically examined. The result will be found detailed in Appendix III. Malaria parasites were only found 45 times. The mean parasite rate for the whole town works out at 10·5 per cent. The rate varies in different areas ; it is to be noted that at H, where the spleen rate is highest, the parasite rate is low. There are various factors to account for this apparent anomaly. The parasites, in all but two instances, were present in very scanty numbers : often but one parasite could be found in a slide, and it is therefore probable that many small infections were overlooked. None of the children were suffering from fever at the time of examination, the infection in nearly every

instance being at a quiescent stage, ready to break out when conditions again became favourable. The gametocyte cell was the one most frequently encountered.

The quartan parasite (Appendix III) predominated, an experience which tallies with the recent work of Major Christophers, I.M.S., in the Andamans.

Malignant or sub-tertian crescents were only found three times. All three species of malaria parasite—the quartan, tertian, and sub-tertian—were represented. It is of great interest to note that malaria parasites were found in the blood of 15 children, in whom *no concomitant enlargement of the spleen could be detected.*

Results of systematic treatment with Quinine. Special enquiries were made during this investigation with regard to the effect of regular treatment with quinine. On the whole, the children impressed me as being a remarkably healthy set, well-fed, mentally alert, with sleek and glossy skins, presenting in this respect a contrast to the anaemic, ill-kept, rough-skinned village children met with in malarious districts in the Southern Province.

It was found that a very small proportion of the children had been regularly treated with quinine—only 43 out of the total number examined had been so treated ; the spleen rate amongst those treated was 60·4 per cent., and the parasite rate 13·9 per cent., as against a spleen rate of 33·8 per cent. and a parasite rate of 9·9 per cent. amongst those who had had no treatment at all. It must be understood that these figures do not represent the real efficacy of quinine treatment; only the cachectic, anaemic children attend the Town Hall for systematic quinine administration, and it is just amongst these that a higher spleen rate is to be expected. Indeed, a considerable improvement in the spleen rate has been effected by systematic treatment, as I understand that on commencing treatment every one of these children had enlarged spleens.

The greatest difficulty with which Gunasekara has to contend is to convince the parents of the children of the necessity for *systematic treatment* after the one attack of fever has ended. The schools are obviously the places where systematic daily administration of quinine pills should be undertaken. In winning over the teachers to his views, Gunasekara, by the exhibition of much tact, has been particularly successful. I understand that this difficulty is greatly magnified, in so far that only 50 per cent. of the children of Kurunegala town regularly attend school.

Fig. 6. Flooded Paddy Fields. (Opposite the Railway Station.) Water supplied from Wenaruwewa tank. This picture shows in the foreground pools formed by the hoof marks of cattle, in which anophelines breed.

Fig. 7. Irrigation Channel. (Behind the Railway Station.) Water supplied from Wenaruwewa tank; stocked with fish. When water subsides stagnant pools are left behind, in these anophelines breed.

Conclusions.

(1) The malaria in Kurunegala is mostly of the quartan type.

(2) That at least six well-known malaria-conveying Anophelines occur in Kurunegala.

(3) That the paddy fields are the main and most extensive breeding areas of these mosquitoes.

(4) That wet cultivation within town limits should be forbidden, as being the only means calculated to abolish endemic malaria. That this measure presents no insuperable difficulties may be seen from the perusal of figures given in Appendix V, where it is definitely stated that the substitution of cocoanut for paddy cultivation is perfectly feasible, and is indeed commercially a profitable venture.

Recommendations.

I venture to put forward the following recommendations based on the facts already related:

(1) Abolition of paddy fields within town limits.

(2) Systematic treatment of all school children with quinine during their attendance at school. This practice to be continued for two years after the abolition of paddy fields. Enforcement of the Town Schools Ordinance of 1908[1].

(3) Cementing all drains and waterways in the town, and more especially the streams in the railway cutting. These drains, after being cemented, must be systematically cleansed of all vegetable growth.

(4) Stringent rules to prevent natives from blocking up streams and irrigation channels for the purposes of washing cattle or of catching fish.

(5) Bund of channel from Wenaruwewa tank which supplies engine sump and paddy fields near station to be kept in repair to prevent leakage.

(6) All irrigation channels should be properly graded so as to serve as outlets for storm water. In this respect the irrigation channel behind the station yard requires attention.

(7) No borrow pits to be excavated within town limits without permission of the Local Board, who alone ought to be responsible for this work.

[1] An Act to enforce regular school attendance.

(8) Rules to enforce adequate disposal of recently opened and discarded cocoanuts for drinking purposes. Owing to the abundance of firewood in Kurunegala, these shells are not used for fuel as elsewhere. In the spacious hollow water collects and forms an ideal breeding ground for all species of mosquitoes.

(9) Enforcement of a "Cattle Straying Ordinance." Could cattle be prevented from straying into paddy fields, the "goiyas" would then be able to reside at a greater distance from their work. At present, although realizing in some instances that these situations are unhealthy, they are unable to move further away on account of the damage to their crops arising from stray cattle.

Appendix I.

Statistics.

435 children examined, mostly between the ages of one and 12 years (there were a few of 14 and one of 16 years of age). 239 of these were males and 196 females.

Total spleen rate 34·7 per cent.; parasite rate 10·5 per cent.

Fifteen children were found with malaria parasites in their blood, who had no enlargement of the spleen.

(*a*) *Spleen rate according to sex*:—Males spleen rate 37·6 per cent.; females spleen rate 29 per cent.

(*b*) *Spleen rate according to age*:

Males			Females		
Age	Number examined	Number with enlarged spleens	Age	Number examined	Number with enlarged spleens
11–12	38	16 or 42·1 per cent.	11–12	9	5 or 55·5 per cent.
9–10	55	29 or 52·7 per cent.	9–10	37	11 or 29·7 per cent.
7–8	41	21 or 51·2 per cent.	7–8	49	15 or 30·7 per cent.
5–6	27	9 or 33·3 per cent.	5–6	38	14 or 36·8 per cent.
3–4	45	7 or 15·5 per cent.	3–4	45	12 or 26·6 per cent.
1–2	33	8 or 24·2 per cent.	1–2	18	—
	239	90 or 37·6 per cent.		196	57 or 29 per cent.

Appendix II.

Note.—Explanatory details with special reference to various villages and collections of houses in Kurunegala, where detailed investigations on the prevalence of malaria were made. Alphabetical latters are employed in designating these areas, and refer to similar letters on the map. For convenience sake the inhabitants of Kurunegala town may be divided into four classes: (1) Government servants; (2) boutique-keepers; (3) villagers or "goiyas"; (4) Tamil oilmongers.

Fig. 8. Railway Cutting. Water-course flowing on each side of the permanent way and supplying locomotives with water. These channels are blocked with weeds, and amongst them larvae of *M. culicifacies* and *M. rossii* were found in abundance.

Fig. 9. A block of houses on the Negombo Road built on the Bund of a paddy field. Inhabitants a good class. Spleen rate 68·1 per cent.

A.—*Habage Village.*—Inhabitants: class (3), "goiyas." Houses scattered, mud and wattle walls, thatched roofs; each house in its own compound. No sanitary arrangements. Houses more or less of same type. Nearest house less than quarter of a mile from nearest paddy field. A block of paddy fields on each side of the village.

96 children examined—55 males and 41 females.

Spleen rate 48·9 per cent.; parasite rate 10·4 per cent.

Eleven children treated regularly with quinine.

B.—A block of brick and mortar cottages inhabited by class (2), "boutique-keepers," situated on Colombo road. Sanitary arrangements better than in most places, one or two latrines being provided. The nearest house is situated only 10 yards from paddy fields.

19 children examined—7 males and 12 females.

Spleen rate 26·3 per cent.; parasite rate 15·7 per cent.

Three children treated regularly with quinine.

C.—A row of well-built wooden houses, mostly shops and boutiques, inhabited by class (1), on Colombo road. Children, mostly police sergeants' and constables', well fed and of a good class. Latrines provided. Nearest house situated quarter of a mile from paddy fields.

10 children examined—4 males and 6 females.

Spleen rate 0 per cent.; parasite rate 0 per cent.

One child treated regularly with quinine.

D.—Row of semi-detached houses on Rajaphilla road inhabited by class (1), police sergeants. Only two years resident in Kurunegala. Children well-fed and well cared for. Houses clean, whitewashed yearly. Latrines provided. Nearest house 20 yards from paddy fields.

19 children examined—5 males and 13 females.

Spleen rate 26·3 per cent.; parasite rate 15·5 per cent.

Three children treated regularly with quinine.

E.—A collection of scattered huts situated near Kandy road inhabited by class (3), "goiyas." Poor houses. Cadjan roof and walls. Each house situated in its own compound. No latrines. Children poorly fed: nearest house situated 10 yards from paddy fields, and from an irrigation channel fed by Wenaruwewa tank one mile outside town limits.

24 children examined—17 males and 7 females.

Spleen rate 66·6 per cent.; parasite rate 4·1 per cent.

Five children treated regularly with quinine.

F.—Quarters of the Tamil oilmongers, class (4), situated on Puttalam road. A bathing tank on one side below Angangalla rock; a tall row of cocoanut and areca-nut palms on the other. Deep tank, one acre in extent, full of fish. No anopheline larvae found. Houses of a very poor description huddled together, built for the most part of mud and wattle with cadjan roofs. Inhabitants overcrowded. No latrines. Back premises where oil mills are situated in a most insanitary condition. Nearest house situated 150 yards from paddy fields, but screened by belt of trees already mentioned.

67 children examined—44 males and 23 females.
Spleen rate 35·8 per cent.; parasite rate 10·4 per cent.
Seven children treated regularly with quinine.

G.—*Gangoda Village.*—A Sinhalese settlement of better class "goiyas" class (3). There is one modern brick house with tiled roof; the rest are of mud and wattle with cadjan roofs. Each house situated in its own compound. No latrines. Nearest house situated within 20 yards of paddy fields containing anopheline larvae. Separated from F by a row of palms.
12 children examined.
Spleen rate 83·3 per cent.; parasite rate 25 per cent.
One child only treated regularly with quinine.

H.—A row of closely adjoining overcrowded houses on the Negombo road inhabited by class (3), "goiyas." Each house with a small compound at the back and provided with a latrine. Houses built of brick and mortar with tiled roof. A number of inhabitants are employed in the cocoanut mills. Children are better fed and cared for than are the majority of the village children. The foundations of the houses are situated on the actual Bund of the paddy fields, as is shown in Pl. XII, fig. 9.
22 children examined—13 males and 9 females.
Spleen rate 68·1 per cent.; parasite rate 4·5 per cent.
Four children treated regularly with quinine.

J.—A congregation of houses scattered over an area of about half a mile in extent amongst cocoanut land and inhabited by class (3), "goiyas," bordered by a block of paddy fields on one side and bare rock on the other. Houses poor; cadjan roof and walls. No latrines. Irrigation channel. A branch of main channel fed from Kurunegala tank runs through the centre of the village. The gradient of this channel is so constructed that the water wells up and leaves pools of stagnant water behind, in which anopheline larvae are found.
25 children examined—14 males and 11 females.
Spleen rate 36 per cent.; parasite rate 12 per cent.
Four children treated regularly with quinine.

K.—*Madagama Village.*—A collection of cadjan houses situated amongst cocoanuts and inhabited by class (3), "goiyas." Ample space between each house surrounded by compound. Small paddy block of one acre in extent within 20 yards of a group of houses. This block is not irrigated, but is filled with rain water, and is cultivated once a year. On the town side there is a large block of paddy fields within 150 yards of the nearest house.
39 children examined—17 males and 22 females.
Spleen rate 35·8 per cent.; parasite rate 12·8 per cent.
No children treated regularly with quinine.

L.—The *Bazaar*, in Kurunegala town itself. Boutiques on each side of the main streets of the town inhabited by class (2), "boutique-keepers and artisans" of all nationalities—Sinhalese, Tamils, Moors, and Malays. Houses: some built of brick, others mud and wattle with tiled roofs. Curry stuffs, dried fish, and sundry articles for sale; grossly overcrowded. Great numbers of children. Some houses have

Fig. 10. Oil-Mill Yards. Ill-kempt and insanitary quarters of the Tamils. The spleen rate here is less than half of that in Gangoda, a Sinhalese village within 200 yards, but separated by the belt of cocoanut and areca palms seen on the right of the picture.

Fig. 11. A borrow Pit. One of the sins of the Public Works Department and a breeding ground of anophelines. Most of these pits have now been filled in.

private latrines. The *only standing water* in immediate vicinity is a rock pool, quarter of an acre in extent, in the quarry.

102 children examined—55 males and 47 females.

Spleen rate 7·8 per cent.; parasite rate 8·9 per cent.

Five children regularly treated with quinine.

APPENDIX III.

Details of Malaria Parasites found.

Malaria parasites were found 45 times in 435 blood specimens.

The quartan parasite greatly predominated.

Quartan found 33 times, tertian found 12 times.

Sub-tertian crescents found three times.

There were two double infections: one a tertian and quartan, the other tertian and sub-tertian crescents.

One of the 33 times in which the *quartan parasite* was found, it existed as the gametocyte stage and the infection was an extremely scanty one in all cases except two. In five instances only one gametocyte cell could be found in the film. In five out of the 11 cases in which the tertian *parasite* was found, the gametocyte stage was also represented; in three instances also one gametocyte cell only could be found in the film. The sub-tertian parasite was found solely in the crescent stage.

APPENDIX IV

Statistics showing the effects of systematic treatment with Quinine Pills.

Of 43 children treated regularly with quinine, 60·4 per cent. had enlarged spleens, 13·9 per cent. had parasites in their blood.

392 had had no regular treatment with quinine, 33·8 per cent. had parasites in their blood.

APPENDIX V.

Figures bearing on the Drainage of the Paddy Fields in Kurunegala.

I am indebted to Mr E. B. Daniels, a recognized authority on paddy land cultivation in Kurunegala, for figures regarding the relative values of paddy and cocoanut lands in Kurunegala.

1. *Valuation of Paddy Land.*—Paddy land in the centre of the town is appraised at Rs. 200 an acre, though the owners' valuation is in some instances lower than this —Rs. 150 an acre. The average value of the best paddy land is about Rs. 250 an acre.

Many of the paddy fields in the town are cultivated but once a year, as the soil has lost its fertilizing power through too intense cultivation.

The crops are easily affected by drought. The yield of paddy from the fields in Kurunegala town is rapidly decreasing. Thus, the return from one block which a few years ago was 40 amunams an acre now averages but 8 amunams for the last two crops, in spite of an ample rainfall. The actual return from paddy land to the owner is, however, far less than this.

It is the custom for the owner to present the seed paddy to the "goiyas" (cultivators), and they in return for cultivating the fields retain half the crop for their own use.

On this basis, average paddy land brings in a return of about Rs. 50 per acre per annum to the owner, as follows:

2 bushels paddy=1 bushel of rice.

8 amunams paddy (40 bushels)=20 bushels of rice.

20 bushels of rice at Rs. 5[1] a bushel=Rs. 100.

Rs. 50 to the "goiya" and Rs. 50 to the owner per annum.

2. *Valuation of Cocoanut land in Kurunegala.*—Cocoanut land in the town is appraised at Rs. 1000 per acre for bearing land. An estimation of Rs. 10 is made for every tree in bearing.

Kurunegala district is a well-known district for cocoanuts. Most of the cocoanut land in the vicinity of the town is old paddy land. Cocoanuts in Kurunegala take on an average between ten to twelve years to come into bearing. The price of cocoanuts has in recent years substantially risen in Kurunegala.

Ten to 15 years ago cocoanuts sold at the highest at Rs. 40 per thousand; for the last six years the price has stood at Rs. 70 per thousand, and is now steadily increasing.

Copra, locally made, is selling at Rs. 80 a candy, the highest price ever reached.

In a fully-bearing cocoanut plantation there are six pickings per annum (every two months). The average number of trees per acre is 60, and the yield per tree averages 60 nuts per annum=3600 nuts per acre per annum; this, at an average price of Rs. 50 per thousand, gives a return of Rs. 180 per acre per annum.

3. *Valuation of Paddy Lands as Building Lots.*—As building lots old paddy lands would bring in a large return. There is at present a great scarcity of housing accommodation in Kurunegala. The Salaries Commission has already drawn attention to this fact. Rents are very high. Latterly, on the outskirts of the town, building lots have been selling at Rs. 2000 per acre. There is reason to believe that building lots within town limits would yield double that figure.

4. *Catch Crops.*—During the period (12 years) in which the cocoanut trees are coming into bearing it is suggested that certain catch crops could be grown. The following are suggested:

Cassava or *Manioc*, a surface feeder, which does not interfere with the growth of the young cocoanuts, and does not impoverish the soil.

Sweet potatoes, a crop which materially aids the cocoanut palm, as its cultivation entails the turning of the soil every six months.

Plantains do well, but do not pay.

Kitchen vegetables: chillies, pumpkins, egg plants, etc. For all these products there is a local market.

[1] The value of a Rupee is equal to 1*s.* 4*d.*

5. *General Considerations.*—From a perusal of the figures given above, it will be seen that the conversion of paddy into cocoanut land in Kurunegala is a commercially sound venture.

The paddy blocks are naturally a marshy soil, and must therefore be surface drained for cocoanut land. I understand that the general configuration of the town presents no insuperable obstacles to efficient drainage.

It only remains to consider how those interested in paddy field cultivation should be compensated. The general local feeling appears to be that immediately wet cultivation within town limits is prohibited, owners will not sell their lands, so that there will be no need for Government to acquire these lands.

As regards the "goiyas," who for generations have been engaged in paddy field cultivation, they will no doubt require some sort of compensation for loss of their occupation. It may be found practicable to allow them to acquire land elsewhere, or to employ them in making and repairing the necessary surface drains.

The malaria statistics obtained in Kurunegala should be compared with similar figures collected in the Southern Province.

The Tangalla district on the south coast is a hot damp low-lying area, the villagers are poor and ill-nourished; their huts are of the meanest description constructed of "cadjan," a sort of cocoanut matting. The inhabitants cultivate small plots of millet and citronella grass; in the vicinity of some of the villages investigated there are large natural swamps and a few irrigated paddy fields.

The adults, but more especially the children, have an unhealthy appearance, they are obviously anaemic, their skins are rough and their bellies protuberant.

Time did not permit me to make a collection of the local anophelines, but from an examination of 65 Sinhalese villagers of all ages I was able to obtain some idea of the intensity of the malaria.

The spleen rate was 86·1 % and the parasite rate 29·2 %. The quartan parasite was found eleven times, the tertian parasite twice; the subtertian eight times (rings three times, crescents five). Double infections were found twice; once tertian and quartan rings; and once quartan rings and subtertian crescents.

In this intensely malarious area nothing has so far been done in the way of preventive measures; it is feared that the free distribution of quinine by the Government Authorities has had little effect in diminishing the frequency or in preventing fresh infections.

The natives are in the habit of attending the hospitals and dispensaries only when suffering from an attack of fever, but not during the intervals. The compulsory distribution of quinine to gangs of coolies, as for instance in the Public Works Department, is an unpopular

measure; the men have a great aversion to the taste of the raw drug in liquid form, and it is feared that more often than not the medicine is thrown away.

A few observations were also made in Badulla (2200 ft.) a town of 6400 inhabitants, the capital of the Province of Uva, and the centre of a large tea-bearing district.

There is a heavy rainfall of 75 ins. per annum and the average temperature is 73° F. The town lies in a hollow, shut in on all sides by precipitous hills rising to 4000 ft.

As in the case of Kurunegala there is a block of terraced paddy fields about 100 acres in extent constantly irrigated by running water.

Epidemics have occurred in the town in recent years, and apparently a considerable number of fresh infections occur in the wards of the Government hospital which abuts the block of paddy fields already mentioned, even though the whole building has been lately efficiently screened with wire gauze.

In the few fever cases I was able to investigate the quartan parasite alone was found.

In the paddy fields adjoining the hospital large numbers of anopheline larvae were secured. *M. barbirostris* and *sinensis*, *Myzomyia rossii* and *culicifacies*, and *M. punctulata* were found to be the most abundant species.

Dr Van Rooyen, the resident medical officer, has in the last two years, been in the habit of treating the paddy fields in the vicinity of the hospital once every week with a strong solution of cresoline; there is no doubt that this substance is an efficient larvicide and is harmless to the sprouting rice-plants, but its effects can only be of the most transient character as it is almost immediately swept away by the water overflowing from the terraces above on to those below.

It is possible that with modifications suited to local conditions the recommendations I put forward in Kurunegala apply to Badulla also. It is essential that the offending block of paddy fields in the centre of the town should be abolished and dry cultivation substituted.

OBSERVATIONS ON THE LARVAE OF FLEAS.

By A. W. BACOT,

Entomologist at the Lister Institute of Preventive Medicine,

AND W. G. RIDEWOOD,

Lecturer on Biology at the Medical School of St Mary's Hospital, London.

(With 6 Text-figures.)

Introductory Remarks.

Fleas are insects that undergo a complete metamorphosis in the course of their development from egg to adult. The eggs laid by the mother are not, as are the eggs of lice, attached in any way to the skin, fur or feathers of the animal on which the parents are parasitic. They fall into the nest, or drop to the ground within the lair or "run" of the host. Hatching takes from three to ten days according to the temperature[1]. The larvae are active, whitish maggots, eyeless and legless, which are not parasitic, but feed on organic matter in the host's bed, or in the dust that collects on the ground in its proximity.

The larva, after undergoing two moults, spins a cocoon, within which it pupates, passing through a longer or shorter quiescent phase, and gradually assuming the adult form. When the perfect insect finally emerges from the cocoon it takes the first opportunity of lodging itself in the fur or feathers of some new host, exhibiting a preference for individuals of the same species as that upon which the parents were parasitic.

[1] For recent observations on the influence of temperature and humidity upon hatching of eggs see *Journal of Hygiene*, VIII. 2, May 1908, *Plague Report* XXIX. p. 244; *ibid.* XI. *Plague Supplement* II. Report LV. Jan. 1913, pp. 304–313; and A. W. Bacot. *ibid. Plague Supplement* III. Report LXIX. Jan. 1914, pp. 482–499, 641–643, 645.

Literature.

The earlier writings on the larvae of fleas, by Leeuwenhoek (1693), Cestone (1699), Vallisneri (1733), Roesel (1749), De Géer (1778) and Westwood (1848), are mainly of historic interest. The precise references to the papers are given by Künckel (1873, pp. 132–134), together with a few remarks as to the scope and value of each.

The memoir by Bonnet (1867) and the recent note by Newstead (1907–8) refer solely to the Jigger Flea (*Sarcopsylla penetrans*), the larva of which differs in several features, particularly in its small size, from the larvae of Pulicid fleas, which are alone considered in the present paper.

Blanchard (1868, p. 631) gives a rather poor figure of the larva of *Pulex irritans* and a few remarks upon the life history, and the figure, given by Taschenberg (1880, Pl. IV, fig. 30), is equally unsatisfactory.

The first paper of any considerable importance that deals with the larvae of fleas is that of Laboulbène (1872), a paper read before the Entomological Society of France in 1862, but not published until 1872. This author describes and figures the egg, larva and pupa of the cat-flea.

Künckel's paper, published in the following year (1873), contains a valuable historical review, and observations on the structure and habits of the larvae of the cat-flea, and a flea (*Ceratophyllus fasciatus*), obtained from a dormouse (*Myoxus nitela*).

Packard (1894) deals fairly fully with the structure of both newly-hatched and full-grown larvae of *Ctenocephalus canis*, and although imperfect in several respects, this paper constitutes the best account of the structure of a flea larva published up to the present time[1].

Eggs.

The eggs of fleas are large enough to be readily seen with the naked eye; they are oval in shape and measure in the different species from 0·4 to 0·6 mm. in long diameter[2]. Examined under a lens they appear

[1] After the manuscript of the present paper was sent to press our attention has been directed to a paper by Dr A. C. Oudemans, published in September 1913. This paper, entitled "Suctoriologisches aus Maulwurfsnestern," and published in the *Tijdschrift voor Entomologie* (LVI. 3, pp 238–280, with seven plates) gives good descriptions and figures of the larvae of *Hystrichopsylla talpae* and *Spalacopsylla bisbidentatus*.

[2] Measurements of the eggs of *Ctenocephalus felis*, *Ctenocephalus canis*, *Ceratophyllus fasciatus* and *Pulex irritans* are given by A. W. Bacot in the *Proceedings of the Entomological Society*, March 1911, p. vi; and to that list may now be added the following: *Leptopsylla musculi*, length of egg 0·4–0·425 mm., width 0·230–0·250 mm.; *Xenopsylla cheopis*, length 0·450–0·475 mm., width 0·3 mm.

as if of pure white wax or china, being slightly translucent, with a smooth, polished surface.

NEWLY HATCHED LARVA.

The larva on hatching is small, slender and semi-transparent, with sparse but regularly disposed hairs. It consists of a head, three thoracic somites and ten abdominal somites, the last being much smaller than the ninth, and provided with a pair of downwardly and backwardly directed processes, the anal struts. On the top of the head of a newly hatched larva is a curious egg-breaker, by means of which a slit is formed in the egg-shell through which the larva emerges. This egg-breaker, first described by Künckel (1873, p. 135) in the larva of *Ctenocephalus felis* and *Ceratophyllus fasciatus*, although previously noticed by Roesel and De Géer, seems to be regularly present; it has been observed by Bonnet (1867) in *Sarcopsylla penetrans*, and by Packard (1894, p. 318) in *Ctenocephalus canis*, and by ourselves in *Pulex irritans*, *Xenopsylla cheopis* and *Leptopsylla musculi*, while its presence in larvae of *Ctenocephalus felis* is confirmed by Balbiani (*Comptes rendus* 1875, p. 904), and in those of *Ctenocephalus canis* and *Ceratophyllus fasciatus* by ourselves. The egg-breaker consists of a more or less pyriform structure, lying in a depression on the upper surface of the head. The upper ridge, which ends in front in the small sharp tooth, is more strongly chitinised than the other parts, and the organ gives one the impression of being capable of inflation and upward extension so as to press the tooth into the inner surface of the egg-shell. Künckel notes (p. 136 and Figs. 2 and 3) that the tooth of the egg-breaker is set farther back on the organ in *Ceratophyllus fasciatus* than in *Ctenocephalus felis*. No trace of the egg-breaker is to be seen in larvae after the first moult.

GROWTH OF THE LARVA.

A newly hatched larva is more cylindrical, *i.e.* of more uniform width, than one of larger size. As the larva grows the fore and hind ends assume a more tapered form; the tapering of the front end is a gradual one from the eighth abdominal segment to the head; the tapering of the hind end, from the eighth to the tenth abdominal segment, is more abrupt. The head does not increase in size at the same rate as the other parts of the body, and so an older and consequently larger larva has a relatively smaller head than a small larva, and the front portion of the body appears more pointed.

At the end of the larval period, just prior to the spinning of the cocoon, the larva becomes less active; it is of a more opaque white colour than before, and the body is shorter and fatter, and with a more conspicuous tapering of the ends. The increase in size in larvae of *Xenopsylla cheopis*, as determined from the measurements of two drowned specimens, is as follows:

	Newly hatched	Full fed, but still active
Length	2·0 mm.	4·5 mm.
Thickness	0·22 mm.	0·47 mm.
Length of head	0·16 mm.	0·21 mm.

During this increase in size the larva moults twice. The average length of a full fed, active larva of *Xenopsylla cheopis* in the living state is 4·2 mm. (average of 15 observations).

The remarks which follow refer particularly to active full-grown larvae, after the second moult and before the development of that excess of fat which indicates the approach of the pupal phase. The species examined in detail are:

Pulex irritans Linn.
Xenopsylla cheopis Rothsch.
Ctenocephalus canis Curtis.
Ceratophyllus fasciatus Bosc.
Ceratophyllus gallinae Schrank.
Leptopsylla musculi Dugès.

Habits of Larvae.

Except in the case of *Leptopsylla musculi*, the larvae of fleas are very active, moving with remarkable celerity through and upon the debris of the nests and dry rubbish among which they live. While naturally active, they become very excited and impatient when disturbed. The larvae, however, have periods of quiescence, during which they lie coiled up in the manner of a watch-spring, either for repose or concealment; on the other hand, when about to moult they lie stretched out at full length.

When moving quietly, the larva crawls over an even surface supporting the body on the ventral hairs or setae, and extending and contracting the segments after the manner of an earthworm. Each seta can be moved independently of the others, as may be seen by watching

a larva partially drowned in weak alcohol, but in crawling the action is so regular and rhythmical that it is impossible to say whether progression is due to independent movement of the various setae.

When the movements are more vigorous, and in travelling over rough surfaces, the larva bends down the head, hooking what one may call its chin over some relatively fixed object, and then by contraction of the longitudinal muscles draws up the rest of the body. The two anal processes or struts ("caudal stylets" of Packard) on the tenth abdominal segment are then turned downward and outward, and gain a purchase upon some roughness of the ground; the body is then elongated, and the raised head slides quickly forwards, until it bends down again and hooks over some other irregularity in the surroundings. The function of the anal processes is thus to prevent any backward slipping when the body is in process of elongation and the head stretching forward for its next effort.

The larvae of fleas are of a semi-transparent white colour, with a yellow or brownish head, but the colour of the body depends to a large extent on the contents of the alimentary canal, and a larva which has recently been feeding on particles of dried blood is darker than one which is fasting, owing to the reddish or blackish alimentary canal showing through the transparent body-wall.

Even as late as 1868 (cit. Blanchard, 1868, pp. 631–632) Montandon's agreeable fable was credited of the mother-flea leaving its mammalian host in order to disgorge into the mouths of its larvae crawling on the ground the blood which it had recently sucked. While this story is now regarded as a pleasing fancy of the imagination of naturalists of the past, it seems nevertheless true that the chief food supply of some (probably most) species is the excreta of their parents, and although some larvae seem to be able to live on any small dry organic fragments they encounter, others, *e.g.* those of *Ceratophyllus fasciatus*, cannot be satisfactorily reared in captivity unless they are supplied with the excreta of adult fleas or particles of dried blood.

Defrance, as far back as 1824, suggested that the small blackish grains found with the eggs and larvae of fleas, and upon which the larvae are known to feed, are not, as was previously thought, the faeces of the parent fleas, but dried drops of blood which have flowed from the wounds of the host inflicted by the adult fleas after they have sucked as much as they required. He based his conclusion on the irregularity in the size and shape of the grains and the fact that when moistened they resemble dried blood rather than fleas' excrement. Recent

observations[1], however, show that Defrance's argument is not sound, for when a flea is in a gluttonous mood, it discharges, not small grains of uniform size, but drops of red, liquid, and scarcely digested blood. These drops and splashes will on drying assume irregular shapes little suggesting that they are anal discharges.

In rearing the larvae of fleas it is essential that the atmosphere should be of the right degree of humidity; the material (sawdust, sand, etc.) in which they are kept should not be wet, on the other hand the larvae soon shrivel up if the air is too dry[2].

Structure of the Head.

The head of the larva has a thicker chitinous covering than the other parts of the body, and appears yellower or browner in colour. The size and shape vary in the different species—in *Xenopsylla cheopis* the head is small and tapers considerably in the front part when viewed from above, whereas in *Ceratophyllus fasciatus* and *Ceratophyllus gallinae* the head is large and rather oval when viewed from above (see Figs. 1 and 2). Intermediate between these two extremes are the heads of *Pulex irritans* and *Ctenocephalus canis*, both of which are narrow in the snout, but less distinctly so than that of *Xenopsylla cheopis*. The head of *Pulex irritans* is larger than that of *Ctenocephalus canis*, and the head of *Ctenocephalus canis* is larger than that of *Xenopsylla cheopis*. The head of *Leptopsylla musculi* is of the same shape as that of *Ceratophyllus fasciatus*, but it is rather smaller.

The mouth is nearly terminal, in the lower half of the head; the most anterior part of the whole head is the upper lip, or labrum, a soft, thin flap which is nearly straight and horizontally disposed, or has the sides bent down, according to the action of the muscles of the mouth. Projecting sideways from the head, and slightly upward and forward, are the two antennae, and projecting forwards, sideways, and slightly downwards are the maxillary palps. The labial palps are very small, situated near the ventral median line of the head, at about one-fourth or one-third of the length of the head from the front. Except for the antennae, and the maxillary and labial palps, the only projections

[1] See results of experiments on the rearing of fleas by A. W. Bacot, *Journal of Hygiene, Plague Supplement* III. Jan. 1914, pp. 466–467, 471–472, 499–500, 513–517, 646–647.

[2] For recent observations on the influence of temperature and humidity upon the rearing of larvae see A. W. Bacot, *Journal of Hygiene, Plague Supplement* III. Jan. 1914, pp. 513–533, 646–647.

from the smooth surface of the head are the setae, and the small processes around the bases of the antennae. The positions of the setae on the head, and their relative sizes, are shown in Figs. 1 and 2.

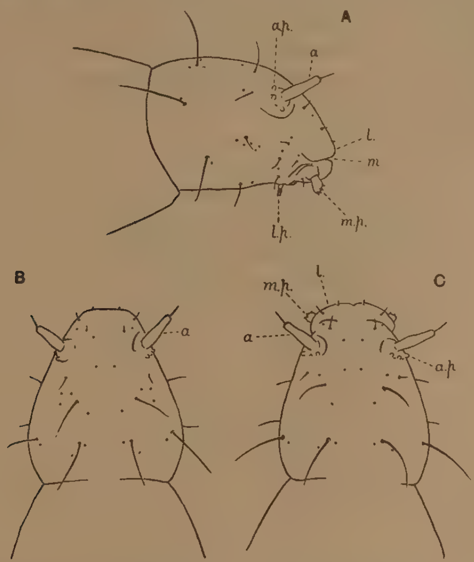


Fig. 1. Head of larva of *Xenopsylla cheopis* (× 110). *A*, right side; *B*, dorsal aspect of a head with closed mouth; *C*, dorsal aspect of a head with the mouth open and the lip well extended. Drawn by camera lucida from unmounted specimens. W. G. R.

a. antenna; *a.p.* papillae around base of antenna; *l.* upper lip or labrum; *l.p.* labial palp; *m.* mouth; *m.p.* maxillary palp.

TABLE I.

Differences in the Characters of the Heads of the Larvae of the six Species investigated.

	Relative size of head	Snout as viewed from above	Number of teeth on mandible	Palp of first maxilla	Papillae at base of antenna
Pulex irritans	large	medium	three	type A	type A
Xenopsylla cheopis	small	narrow	five (occasionally six)	type A	type A
Ctenocephalus canis	rather small	medium	six (occasionally five)	type A	type A
Ceratophyllus fasciatus	large	broad	eight	type B	type B
Ceratophyllus gallinae	large	broad	six	type B	type B
Leptopsylla musculi	medium	broad	eight (occasionally seven)	type B	type B

Antennae.

The antennae are the most prominent appendages of the head; they have the form of long cylinders slightly thinner in the distal one-third of their length, bearing a ring of four minute points at the margin of the extremity, and a central stiff hair, which does not taper, or only slightly. This hair is relatively longer in *Ceratophyllus fasciatus* than in *Xenopsylla cheopis*, and is proportionally longer in newly hatched

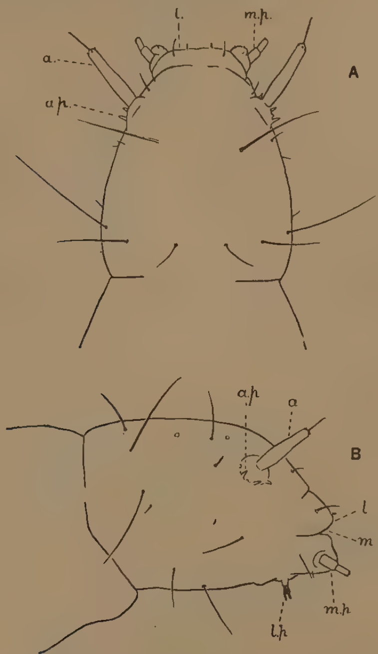


Fig. 2. Head of larva of *Ceratophyllus fasciatus* (× 110). *A*, dorsal view of a head with the mouth open and the lip well extended; *B*, right side of a head with the mouth nearly closed. Drawn by camera lucida from unmounted specimens. W. G. R.

a. antenna; *a.p.* papillae around base of antenna; *l.* upper lip or labrum; *l.p.* labial palp; *m.* mouth; *m.p.* maxillary palp.

larvae than in larvae of the third instar. The antenna stands upon the middle of a flattened dome, like an inverted saucer; and around the posterior half of this elevation is a series of three soft, blunt processes, apparently of a sensory function, alternating with three, rarely two,

smaller, hemispherical processes. In *Pulex irritans*, *Xenopsylla cheopis* (Fig. 1, *a.p.*), and *Ctenocephalus canis* the three large processes are shaped like teats or projectiles (type A), but in *Ceratophyllus fasciatus* (Fig. 2, *a.p.*), *Ceratophyllus gallinae* and *Leptopsylla musculi* they are pointed, and have the form of rather long cones (type B).

Mandibles.

Although adult fleas are provided with piercing and sucking mouth-parts, and live on blood, the larval forms are not parasitic, and have mouth-parts adapted for biting and nibbling. The mandibles, though doubtless they project from the mouth during feeding, cannot in a dead specimen be seen without dissection, or making the head transparent (by dehydrating and clearing with xylol, or by the action of a 15 % solution of caustic potash for three days), when they can be seen by reason of their being darker in colour than the other parts of the head.

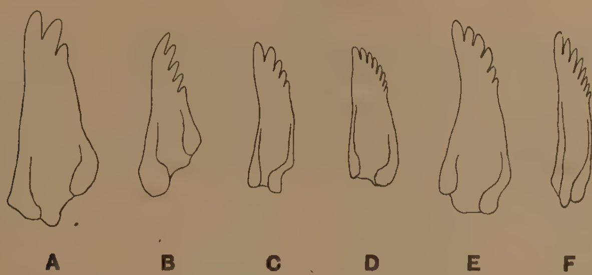


Fig. 3. Mandibles of Larvae of Fleas (×300). W. G. R. *A*, *Pulex irritans*; *B*. *Xenopsylla cheopis*; *C*, *Ctenocephalus canis*; *D*, *Ceratophyllus fasciatus*; *E*, *Ceratophyllus gallinae*; *F*, *Leptopsylla musculi*. All drawn by camera lucida with apochromatic objective 4 mm. and compensating ocular No. 4, and subsequently reduced to three-fourths; it is to be noted, however, that in different full-grown larvae of the same species the mandibles vary considerably in size.

The front part of each mandible is strongly chitinised and ends in a tooth, which is nevertheless more or less in series with the lateral teeth. The mandibles are disposed with their points directed forwards, and their concave faces towards one another. The large terminal tooth is the lowest of the series, and the other teeth are set along the antero-dorsal edge for about one-fourth (*Pulex irritans*), one-third (*Ceratophyllus fasciatus*), or one-half (*Xenopsylla cheopis*) of the total length of the mandible.

In Table I the number of the teeth includes the terminal, forwardly directed tooth. *Pulex irritans* has three fairly stout teeth on each mandible; in the other species the teeth are smaller (see Fig. 3). In *Xenopsylla cheopis* there are five, occasionally six; in *Ctenocephalus canis* six, occasionally five; in *Ceratophyllus fasciatus* usually eight, sometimes seven; in *Ceratophyllus gallinae* usually six; and in *Leptopsylla musculi* eight, occasionally seven.

The same mandible differs greatly in appearance according to the particular angle at which the row of teeth is viewed; in the sketches reproduced in Figure 3 the mandibles are as far as possible so orientated that the lateral teeth are at right angles to the axis of vision, *i.e.* they appear as little fore-shortened as possible. In *Leptopsylla musculi* the mandible is rather narrower than in *Ceratophyllus fasciatus*, and the teeth appear less crowded towards the front end of it, although in both cases the teeth extend over about one-third of the length of the mandible.

Maxillae.

The maxillae (first maxillae) have the form of a pair of brushes, like hair-brushes, but with the bristles restricted to the antero-median half of the upper surface. The bristles are mostly short and curved, but there are at the front of each brush two short, forwardly directed, straight hairs which are two-jointed. The maxillary brushes work against two patches of oblique, curved hairs in the roof of the mouth. The two maxillae, with the labium between them, form the floor of the front part of the mouth. Künckel supposed that each maxilla was like a part of a circular saw, cutting by its edge only (1873, p. 138 and Plate VI, Figs. 7 and 11); he evidently failed to notice the bristles that are directed upwards into the mouth-cavity.

Projecting from the antero-ventro-external part of the maxilla is the maxillary palp (Figs. 1 and 2, *m.p.*), which arises from a broad shallow depression, and consists of two joints. There are among the six species of larvae studied two distinct types of maxillary palp. In the first type, which we may call type A, the basal joint is short and broad, and stands higher on one edge than the other; the second joint is narrower at its base than at its free end, its end is obliquely truncated, and bears five small points, more or less radiating. In the second type, or type B, the basal joint is cylindrical, about twice as long as broad and square-cut at the end; the second joint is much narrower than the first, is cylindrical, rounded at the end, and bears four or five very minute

points (see Figs. 1 and 2, *m.p.*). The palps of the A type occur in larvae of *Pulex irritans*, *Xenopsylla cheopis*, and *Ctenocephalus canis*; those of type B are found in *Ceratophyllus fasciatus*, *Ceratophyllus gallinae* and *Leptopsylla musculi*. It is of interest to note that this division of the six species into two groups according to the characters of the maxillary palps is supported by details of internal anatomy. The salivary glands of the first three species, for instance, have only two lobes, while those of the last three species have three.

We have not examined the larvae of *Ctenocephalus felis*, but, assuming that they do not differ materially from those of *Ctenocephalus canis*—some authorities have denied that the species are distinct, although the differences in the shape of the head and details of the male genitalia of the adults are at the present time considered of adequate specific value—the figures given by Laboulbène (1872, Pl. XIII, Figs. 5, 9, 10, 13) show the basal joint much too narrow and the terminal points in too regular a row, while in Künckel's figure (1873, Pl. VI, Fig. 7) the maxillary palp is distinctly of the B type, and since he was also studying larvae of *Ceratophyllus fasciatus* at the time, the suggestion that we offer is that his Figure 7 represents a ventral view of the mouth of *Ceratophyllus fasciatus*, and not of *Ctenocephalus felis*. This suggestion is supported by the sharpness and the length of the papillae around the base of the antenna in Figure 7, whereas in his Figure 8 the papillae are short and rounded, as we find them to be in *Ctenocephalus canis*.

In an unmounted head the maxillary palps of a larva that has died with the mouth open project in front of the upper lip (see Figs. 1 c and 2 a, *m.p.*). The maxillae are particularly large and prominent in *Leptopsylla musculi*. If the larva has died with the mouth slightly closed, the labium and the maxillae, as seen in a side view of the head, are much retracted, and their external surfaces are disposed in an oblique line extending from the labial palps to the front point of the snout.

Labium.

The labium, a median structure representing the second pair of maxillae, is set in the floor of the mouth, between the two maxillary brushes. It tapers forward to a blunt point, and has the extremity bent downward. Projecting downward from the under surface of the base of the labium is the pair of labial palps, each of which consists of a short basal joint bearing at its extremity four stout bristles. These bristles do not taper; two are short, about three or four times as long

as they are broad; the other two are longer, and are slightly curved (Figs. 1 A and 2 B, *l.p.*). The relations of the parts of the labium are most easily made out in *Ceratophyllus fasciatus*. In *Xenopsylla cheopis* the two maxillary brushes come closer together than in *Ceratophyllus fasciatus*, and the labium is greatly reduced, although the labial palps are clearly recognisable. We have been unable to detect in the larvae of any species a hypopharynx as a distinct structure from the labium; the duct of the salivary gland has the appearance of opening as a groove or gutter on the median part of the labium itself.

Body.

There is no very obvious separation between the thorax and abdomen, except in larvae about to pupate, in which the three thoracic somites show as distinct in form from the abdominal segments. The general somitic divisions of both thorax and abdomen are clear, the constrictions being sharp, though not deep (see Fig. 6). There is a steady increase in the size of the segments backwards from the head to the sixth, seventh or eighth abdominal, after which the segments decrease rapidly to the end. The tenth or anal somite is always small. In *Xenopsylla cheopis* the broadest segments are abdominal somites 7 and 8, and abdominal 9 is only slightly smaller; but in *Ceratophyllus fasciatus* the largest segments are abdominals 6 and 7, and there is a tapering backward and forward from this region; *i.e.* the ninth abdominal somite is relatively smaller in *Ceratophyllus fasciatus* than in *Xenopsylla cheopis*. The larva of a flea is more cylindrical at its ends than in the middle third of its length, where the muscular development produces a lateral flange in each segment similar to that commonly present in Lepidopterous larvae.

In a fully extended living larva, and in a dead one which has been treated with caustic potash solution, there is no appreciable overlapping of the cuticle of the various segments, but in a contracted larva, and particularly in a larva about to pupate, the cuticle of each segment overlaps that of the segment behind. The head is overlapped by the cuticle of the first thoracic segment in a contracted larva.

The chitinous cuticle of the body is unevenly thickened. As in most insect larvae there are definite plates (dorsal plates, etc.) where the chitin is thicker, browner and smoother than elsewhere. These plates are most clearly distinguishable just before the larva moults, and are difficult to make out in a recently moulted larva. In the figures

of *Xenopsylla cheopis* (Fig. 6) the plates are lightly outlined. The various plates can be well seen in a moulted skin, and are particularly distinct in the larvae of *Ceratophyllus gallinae*.

The thinner parts of the cuticle appear soft, smooth and glistening, but under a high power of the microscope they exhibit a peculiar pattern like a fine honey-comb or a shagreen. This pattern is due apparently to slight elevations of the surface, for in *Ceratophyllus gallinae* the surface is definitely raised into close-set rows of backwardly directed, blunt spikes, like the teeth of a coarse rasp. In the more ventral parts of the body the spines are blunter and rounder, and more like those of the larvae of the other species, though coarser. These elevations are not present on the dorsal and other plates of the body, where the chitin is thicker and yellower.

The hairs or setae of the body somites are disposed in more or less transverse rows or rings, and consist of a ring of large hairs near the posterior edge, and a ring of smaller hairs in front of it. The regularity of the rings of small hairs is disturbed in the vicinity of the stigmata, which occur laterally in the first thoracic somite and the first eight abdominal somites. The tracheal system is best studied by drowning a larva in 50 % alcohol. The main tracheae consist on each side of a double longitudinal trunk, linked together in the anterior third of each segment by a fine tube. The stigmata are the minute openings of very slender tubes which extend to the surface from the middle of these links. The right and left lower longitudinal tubes are connected by transverse ventral tubes in the middle of the length of each segment. Laboulbène's figure (1872, Pl. XIII, Fig. 13) is good, except that he shows a stigma on the third thoracic somite. The stigmata lie at the edge of the lateral plate, antero-dorsally to the base of the upper lateral large hair; each stigma is on the lateral elevation of the body, and has three of the finer or anterior hairs disposed around it.

Each of the large hairs arises from the middle of a small circular area of soft and flexible chitin, and in certain positions there are to be found similar circular areas with no hairs arising from them. These last are more noticeable in the larvae of *Xenopsylla cheopis* and *Pulex irritans* than in those of *Ceratophyllus fasciatus* and *Ceratophyllus gallinae*.

The arrangement of the long hairs on the dorsal plates varies in different species, and may in conjunction with other characters be used to distinguish cast skins of larvae. The skins should be softened in warm water or 50 % alcohol, and spread out on a slide. Of the six

species examined *Pulex irritans* is peculiar in having three pairs instead of two on the dorsal plate of abdominal somites 7 and 8, and four pairs on the ninth abdominal somite; *Xenopsylla cheopis* and *Ctenocephalus canis* are peculiar in having but a single pair on the dorsal plates of abdominal somites 1–6.

In recently moulted larvae the dorsal plates are not readily distinguished, and Table II proves of little service. In such cases, therefore, it is better to count the whole of the large hairs on the several somites and refer to Table III. This table, like the preceding, fails to distinguish between *Ceratophyllus fasciatus*, *Ceratophyllus gallinae* and *Leptopsylla musculi*, and between *Xenopsylla cheopis* and *Ctenocephalus canis*.

TABLE II.

Number of Pairs of large (i.e. posterior) Hairs on the Dorsal Plates of the Larvae of the six Species investigated.

	Thoracic somites 1—3	Abdominal somites 1—6	Abdominal somites 7 and 8	Abdominal somite 9
Pulex irritans	2	2	3	4
Xenopsylla cheopis	2	1	2	3
Ctenocephalus canis	2	1	2	3
Ceratophyllus fasciatus	2	2	2	3
Ceratophyllus gallinae	2	2	2	3
Leptopsylla musculi	2	2	2	3

TABLE III.

Number of Pairs of large (i.e. posterior) Hairs carried by the various Somites of the Larvae of the six Species investigated.

	Thoracic somites 1—3	Abdominal somites 1—6	Abdominal somite 7	Abdominal somite 8	Abdominal somite 9
Pulex irritans	5	6*	7*	7*	8*
Xenopsylla cheopis ..	5	5*	6*	6*	7*
Ctenocephalus canis ..	5	5*	6*	6*	7*
Ceratophyllus fasciatus ..	5	6*	6*	5	6
Ceratophyllus gallinae ..	5	6*	6*	5	6
Leptopsylla musculi ..	5	6*	6*	5	6

* On each side of the body the two ventralmost hairs consist of a long and a short one arising close together from the same plate.

For Abdominal Somite 10 see Table IV.

The large hairs of the larva of *Pulex irritans* are much paler and shorter than those of the other species investigated; they are blacker in *Xenopsylla cheopis* than in *Ceratophyllus fasciatus* and *Leptopsylla musculi*. In *Ceratophyllus fasciatus* and *Leptopsylla musculi* the dorsal hairs on abdominal somites 7 and 8 are considerably longer than those on somites 5 and 6, and those on somite 9 are longer still; *i.e.* the posterior hairs of the dorsal half of the body increase in length gradually from abdominal somite 1 to somite 9. In *Xenopsylla cheopis*, on the other hand, they increase in length more gradually from abdominal somite 1 to somite 8, and those of somite 9 are considerably longer. In other

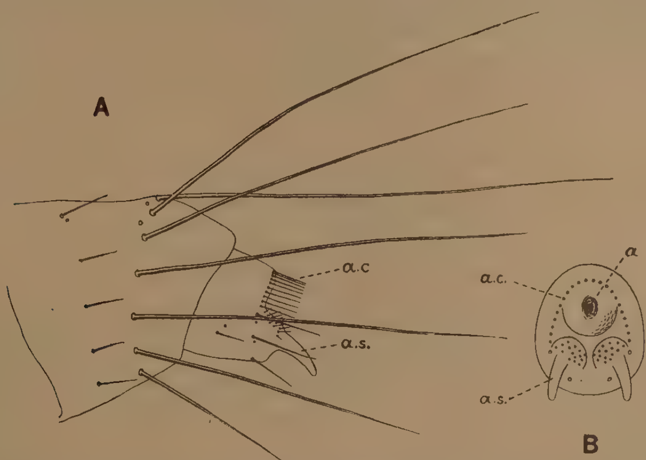


Fig. 4. Hind end of a larva of *Xenopsylla chenopis* (×75). W. G. R. *A*, left side view of the last two somites; *B*, back view of the anal somite (abdominal 10) with the hairs represented as though cropped short.

a. anus; *a.c.* hairs of the anal comb; *a.s.* anal strut.

words, the dorsal hairs of abdominal somites 7 and 8 are in *Ceratophyllus fasciatus* and *Leptopsylla musculi* much longer in proportion to those of somite 9 than they are in *Xenopsylla cheopis*. In *Ctenocephalus canis* the dorsal hairs on abdominal somites 7 and 8 are scarcely longer than those on somites 5 and 6, and those on somite 9 are not nearly so long in proportion as they are in *Ceratophyllus fasciatus*, *Leptopsylla musculi* and *Xenopsylla cheopis*. The dorsalmost pair of hairs on the ninth abdominal somite is the longest in the whole body of a larva, and extends straight backward, instead of radiating in series with the other large hairs of this somite (Fig. 4 A). The ventralmost hairs on

this somite are the smallest of the ring, and there is a gradual increase in length as one follows the series upwards (Fig. 4 A).

The tenth abdominal somite is very much smaller than the others, and the arrangement of the hairs is peculiar. A back view shows the anus a little above the centre, and below this is a pair of mounds carrying the struts or anal processes (Fig. 4 B). The mounds bear a number of fine hairs, and there is a more or less semi-circular row of fine hairs above the anal eminence, constituting the anal comb.

The anal processes or struts are used in rapid progression to prevent any backward slipping of the body, but they are not hard claws as their shape might suggest; the chitinous covering is pale and flexible, and the processes may be to some extent tactile in function. When viewed from the side the struts are slender, curved, tapering, and pointed at

Fig. 5. Anal struts of flea-larvae seen from the left side ($\times 100$). W. G. R.
A, Ceratophyllus fasciatus; *B, Pulex irritans.*

the extremity in *Pulex irritans* (Fig. 5 B) and *Ctenocephalus canis*, and they are longer in *Pulex irritans* than in *Ctenocephalus canis*; in *Xenopsylla cheopis* they are slightly thicker, less curved, and blunter (Fig. 4 A, *a.s.*). In *Ceratophyllus fasciatus* (Fig. 5 A), *Ceratophyllus gallinae* and *Leptopsylla musculi* the struts are thick, nearly straight, and blunt at the ends; they are smaller in *Leptopsylla musculi* than in the two species of *Ceratophyllus* examined (see Table IV). It is of interest to note that in *Pulex irritans*, *Xenopsylla cheopis* and *Ctenocephalus canis* the anal struts are straighter, blunter and less tapered in a newly-hatched than in a full-grown larva.

The anal comb in *Xenopsylla cheopis* (Fig. 4, *a.c.*), *Pulex irritans* and *Ctenocephalus canis* consists of a single semi-cylindrical comb of about 22 fine straight hairs, arranged parallel with one another in very regular series, and the series is continued below in the form of two or three pairs of larger hairs set at wider intervals apart. In *Pulex irritans* these ventro-lateral hairs are as many as five pairs (Table IV). In *Ceratophyllus fasciatus*, *Ceratophyllus gallinae* and *Leptopsylla musculi* the anal comb has a more ragged appearance, which is due to the fact that the comb is double, consisting of a principal comb of about seven

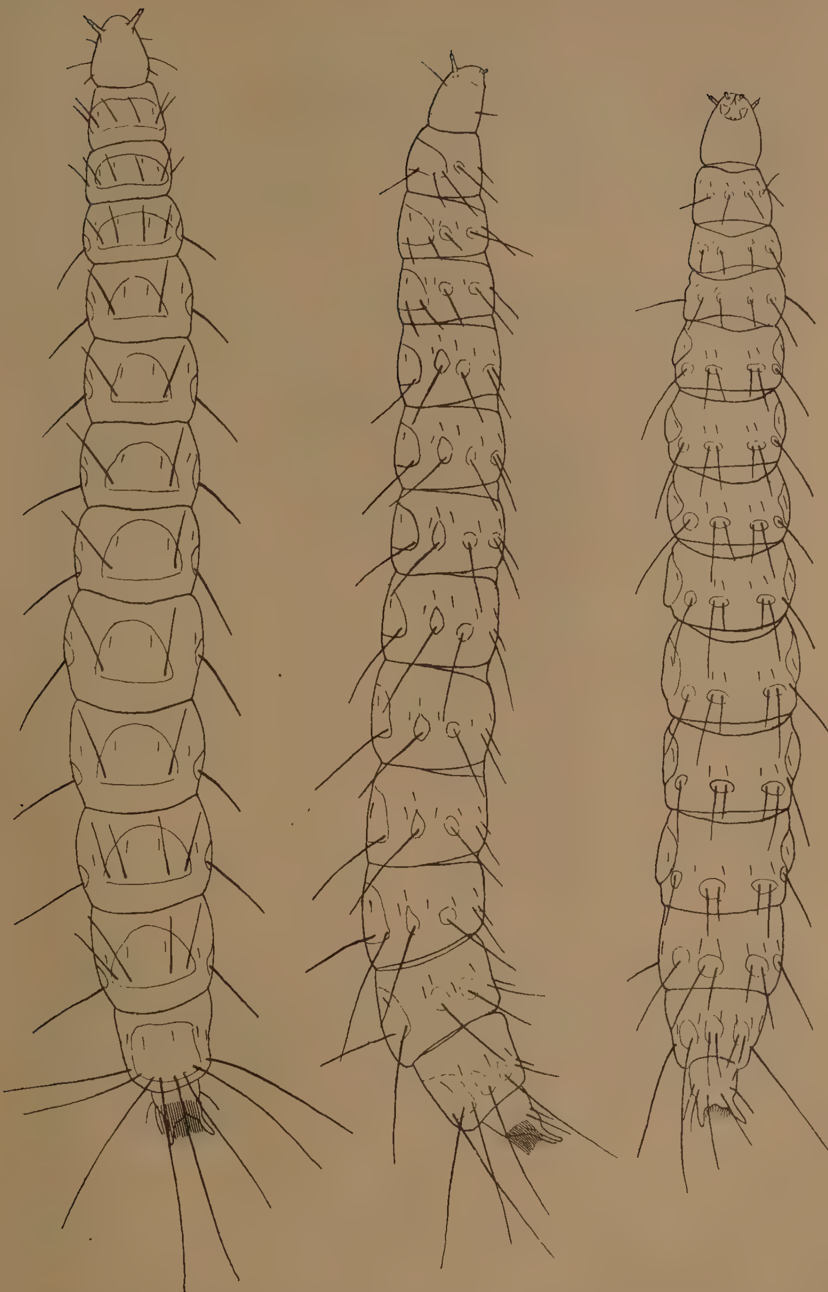


Fig. 6. Larvae of *Xenopsylla cheopis* (×38). A. W. B. Camera lucida drawings of full-grown larvae drowned in weak alcohol. Dorsal view, right side and ventral view.

pairs of hairs, set wider apart than in *Xenopsylla cheopis*, and in front of this another comb of three or four pairs of hairs. What adds to the ragged appearance of the comb is the fact that the hairs project outward as well as backward, whereas in *Xenopsylla cheopis* (Fig. 4 A, *a.c.* and Fig. 6), *Pulex irritans* and *Ctenocephalus canis* they project

TABLE IV.

Differences in the Characters of the Terminal Somite (*Abd.* 10) *of the Larvae of the six Species investigated.*

	Anal comb of fine hairs	Ventro-lateral large hairs in series with the hairs of the anal comb	Anal struts as viewed from the side
Pulex irritans	Single; 11 (occasionally 10 or 12) pairs	5 pairs	Thin, curved, tapering
Xenopsylla cheopis	Single; 11 (occasionally 10, 12 or 13) pairs	2 or 3 pairs	As in *P. irritans*, but rather blunter
Ctenocephalus canis	Single; 11 (occasionally 12, rarely 13) pairs	3 pairs	As in *P. irritans*, but smaller
Ceratophyllus fasciatus	Double; Principal comb of 7 pairs. Anterior comb of 4 pairs	3 pairs	Thick, straight or very slightly curved, only slightly tapered, blunt ended
Ceratophyllus gallinae	Double; principal comb of 5–8 pairs. Anterior comb of 2–4 pairs	3 pairs	As in *C. fasciatus*
Leptopsylla musculi	Double; principal comb of 6–7 pairs. Anterior comb of 3–4 pairs	3 pairs	As in *C. fasciatus*, but smaller

backward only, and are thus parallel with one another. The bases of the hairs of the principal comb, also, in *Ceratophyllus fasciatus*, *Ceratophyllus gallinae* and *Leptopsylla musculi* are not exactly in a line; in some cases, indeed, the bases of the small hairs above the anal eminence are so irregular that they seem to be set in three rows rather than in two.

REFERENCES.

Blanchard, E. (1868). *Métamorphoses, mœurs et instincts des Insectes.* Paris, 1868 (second edition, 1877).

Bonnet, G. (1867). Mémoire sur la Puce pénétrant ou Chique. *Archives de médecine navale,* viii. Paris, two plates.

Defrance, —. (1824). Notice sur la Puce irritante. *Ann. des Sci. Nat.* i. 440–443.

Künckel, J. (1873). Observations sur les Puces, en particulier sur les Larves des Puces de Chat et de Loir (*Pulex felis* et *Pulex fasciatus*). *Ann. Soc. Ent. France,* Sér. v. iii. 129–142, one plate.

Laboulbène, A. (1872). Métamorphoses de la Puce du Chat (*Pulex felis,* Bouché). *Ann. Soc. Ent. France,* Sér. v. ii. 267–274, one plate.

Newstead, R. (1907–8). Insects and other Arthropoda collected in the Congo Free State, by Newstead, R., Dutton, J. E., and Todd, J. L. *Ann. of Trop. Med. and Parasitology,* Liverpool, i. Pulicidae, 93–4, one plate.

Packard, A. S. (1894). On the Systematic Position of the Siphonaptera, with Notes on their Structure. *Proc. Boston Soc. Nat. Hist.* xxvi. 312–355, 35 text-figures.

Taschenberg, O. (1880). *Die Flöhe.* Halle, pp. 122, 4 plates.

THE POSTERIOR STIGMATA OF DIPTEROUS LARVAE AS A DIAGNOSTIC CHARACTER: WITH ESPECIAL REFERENCE TO THE LARVAE INCRIMINATED IN CASES OF MYIASIS.

By MALCOLM EVAN MACGREGOR, B.A. (Cantab.), F.R.M.S.,
Carnegie Student in Medical Entomology.

(*From the Bussey Institution, Forest Hills, Boston, Mass.*)

(With Plates XIV—XVI and 3 Text-figures.)

During investigations at the Bussey Institution on the rôle played by certain dipterous larvae in experimentally induced myiasis, with the object if possible of clearing a little of the doubt with which so much of the question is shrouded, the need of good diagnostic characters for these larvae was brought forcibly to my attention.

This need is one that is felt both by entomologists and physicians, since, when cases of myiasis are met with, it is of the greatest importance that the species of fly concerned shall be readily determined without the need of rearing the larvae to the adult stage, at best a method that can but seldom be undertaken, owing to the fact that the material that one has to pronounce upon is often dead. Thus at the suggestion of Dr Wheeler and Mr Brues, a careful comparison of the morphological characters of the posterior stigmata was undertaken, and though this cannot claim to be in any way the first of such studies, since there are many good illustrations of the various forms of stigmata occurring in the different larvae, notably in Dr C. Gordon Hewitt's book, *The House-fly*, and Mr Nathan Bank's paper on *The structure of certain dipterous larvae, with special reference to those in Human Foods*, as well as in the works of other authors, including several old papers; yet I think

the subject has hardly been given the attention it deserves. I have endeavoured therefore to secure actual photomicrographs of these organs, under the moderately high powers of the microscope, and while these are not in every case quite as clear as some of the other illustrations already mentioned, they are both more accurate and show the remarkable differences more clearly.

Technique.

The aim has been to obtain a method that will envolve the least difficulty in the determination of any particular larva, and the method of preparing the specimens for identification will therefore first be briefly dealt with. This rests on the every-day principle of removing the whole of the softer tissues by boiling in potash, so as to leave only

Text-fig. 1. Diagram showing method of splitting the edge of the cuticle in specimens before mounting.

the chitinous structures intact. The larvae are hardened in absolute alcohol for several days, and are then sectioned by hand, without imbedding, with a keen microtome knife or, what does almost better, a carefully sharpened Gillete razor blade. With the larva held between the finger and thumb, posterior end uppermost, about $\frac{1}{32}''$ is cut off, care being taken that the blade passes below the stigmal plates which are seen usually as two little yellowish-brown dots lying on each side of the middle line at the posterior end of the animal. The section is then examined under the low power of the microscope, to ascertain that the stigmata have suffered no injury, and if possible when the section is large enough the periphery of the cut edge of the cuticle is carefully split by slight incisions with the razor at four points at right angles to each other, as shown in Text-fig. 1.

The next procedure is to put the section in 10 % KOH solution, which is raised to the boiling-point and kept boiling gently until the specimen is quite free from all attached tissue, and only the chitinous structures remain. After removal from the KOH solution, it is washed in water thoroughly, dehydrated in the usual way, and cleared in clove-oil. It is then transferred to a drop of balsam on a slide, and arranged with the exterior surfaces of the stigmata upwards. A coverglass is applied, and gentle pressure administered over the object by means of a clip, until the balsam has set, in order to get the object as flat as possible.

The pressure must be most carefully adjusted however, as some specimens are extremely delicate.

The Structure of the Stigmata.

Owing to the great difficulty of obtaining material in the winter-time, my observations (which in this paper are given merely in preliminary form) are necessarily confined to comparatively few genera, and one is thus unable to predict what degree of variation in form and structure of the stigmata may occur in other genera and species, but there is no reason to suppose that these would not exhibit equally marked variation; as is borne out to some extent by other examples besides those published here, and also by the rough illustrations that, here and there, are to be found scattered through the literature on the anatomy of dipterous larvae.

Of these forms of stigmata there are two main types which may be classed under the following headings, namely the schizotreme-type and ptychotreme-type (see Plate XIV, fig. 1 and Plate XV, fig. 7), and these it would seem, from the material studied, coincide individually with the main taxonomic relationships of the insects: that is, it appears in many cases that related genera have the same main type of stigmata, while the one genus is distinguished from the other by variations in

(1) the orientation of the stigmata with reference to the angle made to the longitudinal axis of the larva;

(2) in the distance between the stigmata themselves;

or, (3) by variations of the gross structure, and shape of these organs: such as a thickening or otherwise of the chitinous ring that borders them, etc.

The specific differences are to be found in the quite often remarkable variations that occur in the finer structure, *i.e.* in the transverse bars

of the slits, both as to arrangement and number, as well as the variation of the position of the " button " (*vide infra*).

In addition to these two main classes, there are several other forms, which occur particularly in the Oestridae. These forms differ from one another so remarkably that it will be sufficient to describe them individually, as each is quite characteristic of the genus to which it belongs.

The Variability of the Form of the Stigmata.

In the same genus and species there is apparently remarkably little variation in the position and structure of the posterior stigmata in the larvae (once these have reached the second instar), but the variation in the different genera and species that have been available for study is so marked that the most casual observer would have no difficulty whatever in recognising them.

Under the two headings already mentioned, into which the types of the stigmata may be classed, a brief description of the most salient characters of each will now be given.

The Schizotreme-type of Stigmata.

The vast majority of the stigmata examined belong to this class. Essentially they constitute two almost circular chitinous plates, with thickened edges, forming distinct rings that enclose the whole organ.

The plates may be arranged at varying distances from one another at the posterior end of the larva, and as nearly as possible on each side of the median sagittal plane; while they may be placed also

(1) above the median horizontal plane,
(2) in this plane, and
(3) below this plane.

Whatever the actual position in this regard, the slits of the schizotreme-type however seem to be invariably three in number but the angle which they make with each other, and with the median sagittal plane, is very often, in the different genera and species, quite specific.

These slits are spanned by delicate chitinous bars, which may pass from one side of the slit to the other, either as simple straight rods, or as rods having one or more branching processes that anastomose with the processes from other rods, and thereby form a network.

In many of the more complicated examples, examined under the microscope, there appear what at first sight might be taken to be nuclei

at the bases of these rods, but these "nuclei" are merely the optical effect produced by the intersection of rods, or processes from them, at another focal plane. In every case the slits are very much longer than they are broad; are usually all about the same length (although in some instances the second slit is somewhat longer than the other two); and the extremities are always rounded off.

In most larvae, at the inner side of the circumference of the plate, or, as is the case generally, situated on the ring, there is what has been previously referred to as the "button," a term used by Mr Banks. This structure, so far as I have been able to determine, is the place of attachment of muscles. It is not however invariably present in the slit class of stigmata, but its exact position, when it does occur, varies in different species, and is, when taken in conjunction with others, one of the characters on which the differentiation of the larvae can be based.

The thickened periphery of the stigmal plate, which has been called the "ring," is sometimes incomplete, and when this is so it is at the region where the "button" ought to be situated that this break often occurs. An example of such a condition is to be found in the Sarcophagidae. The significance of this condition I have not been able to discover, but it is a valuable character in the work of diagnosis, since only two examples of this arrangement have yet been found, namely in the Sarcophagidae and in *Chrysomyia.*

The Ptychotreme-type of Stigmata.

Examples of this type are somewhat less numerous than those of the preceding type, and while for the most part the arrangement is to a great extent similar to those just described, yet in many details they are entirely unlike. The "ring" is usually very well marked, but sometimes the chitin of the plate is so dense that the inner margin of the "ring" is difficult to distinguish. Within the "ring" however there is arranged a chain, convoluted to a varying degree, and with remarkably different configuration according to the different species. It may be either in the form of an unbroken chain, or broken into segments, as in Plate XV, fig. 8; but in this class are included only those forms of stigmata which have a distinct convoluted chain, of one kind or another, within the outer chitinous ring; and to decide on this point as to whether a particular type does, or does not, belong to this class has never been found a matter about which there could be much doubt. The typical examples of the class here illustrated are those of the house-fly (*Musca*

domestica), and the stable-fly (*Stomoxys calcitrans*). Nevertheless some care has to be taken in recognising one or two stigmata of the ptychotreme-type, for although the convoluted chain is always present its recognition may be rendered difficult by the chitin of the "ring" having become so extended that it lies as a plate below, leaving spaces only at intervals where the course of the chain can be seen. A case of this sort is met with in the stigmata of the horn-fly (*Haematobia serrata*). However, by careful focussing there is actually no difficulty in recognising the chain even in this case, especially when the attention has once been drawn to this not very commonly occurring condition.

In the ptychotreme-type of stigmata the "button" is always present, and usually very distinct, and in some cases where the stigma is bounded by a very delicate chitinous ring, chitinous processes often run out to it like irregularly arranged spokes in a wheel, and no doubt serve as supporting pieces.

The two classes, schizotreme-type and ptychotreme-type, are no doubt homologous with one another if the latter be regarded as a simple difference leading from a radiant to a convoluted arrangement; and this idea is to a degree supported by the fact that there are usually three breaks in the course of the convoluted chain, as there are also three slits in the other type of stigmata.

Descriptions of the Stigmata illustrated.

I will now give a brief description of the individual stigmata here illustrated, together with one or two others, beginning with the schizotreme class first. As the typical example of this class the stigmata of *Lucilia caesar* may be selected.

Lucilia caesar Linn. (Plate XIV, figs. 1 and 2.)

These stigmata in the fully formed larvae occur as two fan-shaped stigmal plates, from 0·44 mm.–0·46 mm. in breadth, and lying from 0·40 mm.–0·48 mm. apart, when the distance measured is from the centre of one "button" to the centre of the other. The "button" in this genus is well developed, and the "ring" is delicate and sharply delimited from the rest of the plate. The slits are three in number, and are crossed by from 11–14 separate relatively broad bars, which run from the extreme edge of the one side of the slit to the extreme edge of the other. Between these bars the gaps are large, fairly equal in size, and clearly outlined: their longitudinal measurement being usually greater than the breadth of the bars.

Cynomyia cadaverina Desv. (Plate XIV, figs. 3 and 4.)

The stigmata of this larva appear also as two fan-shaped plates. Although the actual size and shape of each plate, and the distance between them, are almost the same as in *Lucilia caesar*, there are wide differences which distinguish the two genera. The "ring" in *C. cadaverina* is rather more heavily chitinised, the "button" is larger, and more densely surrounded with chitin, while the angles which the slits make to the median sagittal axis of the larva are very much greater.

Moreover there is an essential difference in the arrangements of the bars which cross the slits. These instead of running from the extreme edge of the one slit to the extreme edge of the other, as in *Lucilia caesar*, start a little distance from one side of the edge and run over to an equal distance beyond the other edge, tending to arch over the gap to some extent (fig. 4). This arrangement gives a characteristic appearance not found in any of the other genera that have been examined. The breadth of the stigmal plate in this case is from 0·52–0·56 mm. and the distance between the "buttons" from 0·48–0·53 mm.

Calliphora vomitoria Linn. (Plate XV, figs. 5 and 6.)

In the larva of this fly the stigmata are considerably larger than those of the larvae of the preceding two genera, being from 0·60–0·68 mm. in breadth, with the distance between the "button" of the one plate and the "button" of the other ranging from 0·56 mm.–0·64 mm. The "ring" is very heavily chitinised, and the "button" well marked. The angles of the slits are very much the same as in the case of *Lucilia caesar*, but here again the characteristic difference of the genus is found in the bars that cross them. These are far more numerous than in the other examples described above, and though in this case they run from the extreme edge of the one side to the extreme edge of the other, as in *Lucilia caesar*, they are nevertheless only about half the breadth, and from 20–24 in number for each slit.

Sarcophaga sarraceniae? Riley. (Text-fig. 2 *b*.)

In the stigmata of this species we meet several remarkably different features. The most striking is perhaps the position of the slits. Instead of making wide angles with one another, they approach a parallel arrangement, and what is still more noticeable, are arranged so that

they are not far from being parallel also with the median sagittal plane of the larva. The slits themselves are comparatively broad, with the bars arranged at the "extreme edge" position. Of these there are a fairly large number, but their form resembles that found in *Lucilia caesar*, rather than that of *Cynomyia cadaverina*.

Another strikingly different feature, and one, as has been already said, that has only been found to be shared by *Chrysomyia* (sp. *incert.*), occurs in the "ring." In the stigmata of *Sarcophaga sarraceniae* this "ring" is especially distinct and delicate, but at the point where in the other specimens the "button" is situated, the "ring" is broken and a gap occurs. Thus in the stigmal plate the "button" is absent altogether, though the broken ends of the "ring" are somewhat

Text-fig. 2. Posterior stigmata of (*a*) *Sarcophaga sarraceniae* and (*b*) *Chrysomyia* (?). Diagram of one plate of each to show different arrangement of slits.

thickened and rounded. Taking into account first the almost parallel arrangement of the slits, and then this latter feature, the larvae of this fly are very easily recognised, and there is no need to consider also the finer structure in order to differentiate it satisfactorily from all the others except *Chrysomyia* (?). From this genus it can however be distinguished by the fact that in *Chrysomyia* (sp. *incert.*), though the general arrangements of the slits and the "ring" are similar to those of *Sarcophaga sarraceniae*, in the former the slits, while parallel with one another, are diagonally arranged, and cannot in any way be considered as parallel with the median sagittal plane of the body.

Chrysomyia sp. *incert.* (Text-fig. 2 *a*.)

The general arrangements of all parts of the stigmata are similar to the stigmata of *Sarcophaga*, but differ in the manner described, *i.e.* in the angle that the slits make with the median sagittal plane, and in the fact they are obliquely parallel with one another.

The Ptychotreme-type of Stigmata.

As the typical example of this class, the stigmata of the house-fly (*Musca domestica*) will be taken. In this class the stigmal plate is rather different from that found in the schizotreme-type, tending to be more circular, or in some cases triangular, than fan-shaped: while the position of the "button" is also different, since when this occurs instead of lying on the "ring" it is situated within it, and usually on a line with the horizontal diameter, either touching the inner side of the "ring," or removed some little distance from it.

Musca domestica Linn. (Plate XV, figs. 7 and 8.)

In the larva of this fly the "ring" is always very heavily chitinised, and may be as narrow as in the example shown in fig. 7, or it may be very much broader. The periphery of the "ring" slopes forward (*i.e.* with reference to the anterior end of the larva), so that the stigmata become saucer-shaped, with the concave surface applied to the animal. The exterior surface, which may be regarded as the bottom of the saucer, is flattened, and it is upon this that the convoluted or undulating chain occurs.

This chain consists of a chitinous net-like band, due to a complicated anastomosis of the rods, and is somewhat similar to the arrangement of the rods spanning the slits of the schizotreme-type of stigmata. At first sight, under the low powers of the microscope, the chain appears to be continuous, but on closer observation it is seen to be made up of three sections which are very easily distinguished under the higher magnifications. Taken as a whole the chains of each stigmatic plate have nine complete convolutions in their course; when these are counted by the crest of each wave, but under the high magnifications again, it can be seen that they occur actually as three convolutions to each of the three sections.

Breadth of plates, 0·24–0·28 mm.; distance between "buttons" 0·25–0·30 mm.

Stomoxys calcitrans Linn. (Text-fig. 3 *b*.)

In larvae of this fly the "rings" of the stigmal plates are, roughly, triangular in shape with the adjacent sides straightened and parallel. The "button" is relatively very large, and heavily chitinised, and situated near the middle of the plate. On three sides of the "button," and at right angles to one another, are the three sections of what may be regarded as the broken convoluted chain, with an S-shaped configuration, and very clearly defined. Each section of the chain is crossed throughout its length by a branching bar system similar to that seen in the other types of stigmata, except that in this case the bars are exceedingly slender, and though they can be vaguely made out under the higher powers of the microscope ($\frac{1}{6}$ objective and $\times$ 5 ocular), it needs the very highest combinations ($\frac{1}{12}$ oil imm. objective and $\times$ 12 ocular), to resolve them clearly. Under a magnification of 1440 diams. the bar system can be seen to consist not, as in the stigmata of *Lucilia caesar*, of a single line of branching rods, but of a series of rods in more than one plane which thus produce a most complicated network, the interstices of which measure only a few microns across. The general appearance of the stigmata of *Stomoxys calcitrans* nevertheless, even at low magnifications, is quite characteristic, and cannot easily be mistaken for any other. The measurements of the stigmata are as follows: distance between "buttons," 0·22–0·26 mm.; breadth across plate, 0·28–0·30 mm.

Haematobia serrata Desv. (Text-fig. 3 *a*.)

Of all the forms described in this paper this has yielded the least definite anatomical data; for two reasons: first, that the chitinous "ring" and stigmal plate generally are so heavily chitinised, that mounted in the manner described they are almost opaque to transmitted light under the microscope, except at irregular spots; and secondly that owing to scarcity of material I have not been able to make a sufficient comparative study. That this form of stigmata belongs to the ptychotreme-type there can be no question, however, because by careful manipulation and focussing of the microscope the convoluted chain can be traced over its whole length, while it is very clearly seen at the irregular spots mentioned above where the chitin of the plate is not so thick. That the chain lies well above the heavier chitinous structures of the plate, as with the other stigmata belonging to the ptychotreme-type, is particularly well seen in this larva, for it is situated

at a plane so much higher than these structures that when they are in sharp focus there is not the slightest indication of the chain's presence, and the microscope has to be racked up several revolutions of the fine adjustment before it in turn comes into focus. Here again the convoluted chain is broken into three segments which have a similar position to those of *Stomoxys calcitrans*, but differ so markedly in the extraordinary arrangement of the convolutions that there is no possibility of mistaking the one for the other. The form of one segment of each is shown in Text-figure 3 *a*, and the measurements of the stigmata are: distance between "buttons," 0·27–0·28 mm.; breadth of plate, 0·23–0·25 mm.

Text-fig. 3. Diagram showing the difference in the form of one segment of the convoluted chain in the stigmata of (*a*) *Haematobia serrata* and (*b*) *Stomoxys calcitrans* respectively.

Gastrophilus equi Clark.

(Plate XV, figs. 9, 10 and Plate XVI, figs. 11, 12.).

In *Gastrophilus equi* we meet with a very unusual condition, in that the stigma occurs as a single large plate, which may be regarded as formed by the fusion of the usual two stigmal plates found in those larvae that have been already considered. The fusion may be regarded as having taken place at the top and bottom of each of these two plates, while the parts between have become modified, and hollowed out, so as to leave a gap midway between, into which, one from above and one from below, two tongue-bars project (see fig. 9). On each plate, and running in sinuous parallel arrangement with one another, are three chitinous structures which remind one of the "slits" in the schizotreme-type of stigmata, and like these are crossed by bars. These bars, nevertheless, are more widely set apart, and rarely have a tendency to branch in the same way as those of the other types: moreover their finer structure is entirely unlike that found in the previously described

specimens. It consists, as will be seen in fig. 12, of rods that are thickened at their centre in such a way that a diamond or square-shaped formation results, which is hyaline to some extent and highly refractive, so much so that at the high magnifications that have to be used when examining this structure, it has not been by any means easy to feel certain when its true focus had been attained.

The base on which these sinuous "slits" are placed, and which has been referred to as the "plate," when examined from the exterior surface presents the appearance described above, *i.e.* an appearance suggesting its possible formation by the fusion of the two separate plates found in the schizotreme- and ptychotreme-types of stigmata: examined from the under surface of the section however, a strikingly beautiful and remarkable structure is seen. Observed in this position, there can be seen, arising at regular intervals on the lower surface of the plate, six to eight chitinous processes, which curving upwards fuse with a small ring directly above the centre at the back of the plate, and thus form, as it were, a gourd-shaped basket. I was fortunate enough to be able to obtain a fairly large number of these larvae alive from the stomach of a horse that was autopsied at the Vaccine Laboratory here, and was in this way permitted to study the stigmata in much greater detail than has been the case with many of the other specimens, in that the physiology as well as the anatomy could receive attention. It would be beyond the purpose of this paper to discuss the former subject here, but it might be interesting to state that the physiology of these organs appears by no means as simple as it has been supposed, and that while the sinuous bar systems, or so-called "slits," have been described as lying on the plate, they are in reality attached to a very delicate transparent membrane which covers it, and in the fresh larvae it has been found possible, under the microscope and using special instruments, to dissect off this membrane, bringing away with it the bar systems intact (see fig. 11). Breadth of stigmal plate, 2·6–3·1 mm.

Oestris ovis Linn. (Plate XVI, figs. 13 and 14.)

Here again the stigmata are found to be two separate plates, but the conspicuous "ring" is entirely absent. These plates are from 1·20–1·26 mm. in breadth, and the distance from "button" to "button" is from 1·24–1·30 mm. The "buttons" are very well defined, and from them there radiates over the entire surface of the plates a very

conspicuous dense chitinous network, resembling very much in arrangement the appearance of a mycelium of some fungus growing on culture medium, or the "picture" produced by the cathode electric brush-discharge on a photographic plate. It is a type unlike anything else that has been described, or found in any of the specimens yet examined, and in the Oestridae there seems to be the greatest difference in the form of the stigmata, each genus apparently having its own individual type.

In conclusion I should like to thank Dr Wheeler and Mr Brues for their help and suggestions, which at all times they have been so ready to give; and Drs Ernst and Wolbach, of the Harvard Medical School, for their courtesy in permitting me to use the most excellent photomicrographic apparatus that they possess, without the use of which I could have made very little of these difficult subjects for photography.

DESCRIPTION OF PLATES XIV—XVI.

NOTE: magnifications given are only approximate.

Fig. 1. Posterior stigmata of *Lucilia caesar*, ×50 diams., showing both plates *in situ*.

Fig. 2. Posterior stigmata of *Lucilia caesar*, ×140 diams., showing one stigmal plate.

Fig. 3. Posterior stigmata of *Cynomyia cadaverina*, ×50 diams., showing both plates *in situ*.

Fig. 4. Posterior stigmata of *Cynomyia cadaverina*, ×150 diams., showing one stigmal plate.

Fig. 5. Posterior stigmata of *Calliphora vomitoria*, ×40 diams., showing both plates *in situ*.

Fig. 6. Posterior stigmata of *Calliphora vomitoria*, ×120 diams., showing one stigmal plate.

Fig. 7. Posterior stigmata of *Musca domestica*, ×75 diams., showing both plates *in situ*.

Fig. 8. Posterior stigmata of *Musca domestica*, ×225 diams., showing one stigmal plate.

Fig. 9. Posterior stigmata of *Gastrophilus equi*, ×30 diams., showing the single stigma.

Fig. 10. Posterior stigmata of *Gastrophilus equi*, ×60 diams., showing the bar system in greater detail.

Fig. 11. Posterior stigmata of *Gastrophilus equi*, ×40 diams., showing the bar system on the membrane.

Fig. 12. Posterior stigmata of *Gastrophilus equi*, ×100 diams., showing the bar system on the membrane in greater detail.

Fig. 13. Posterior stigmata of *Oestris ovis*, ×30 diams., showing both plates *in situ*.

Fig. 14. Posterior stigmata of *Oestris ovis*, ×80 diams., showing one stigmal plate.

Fig. 1.

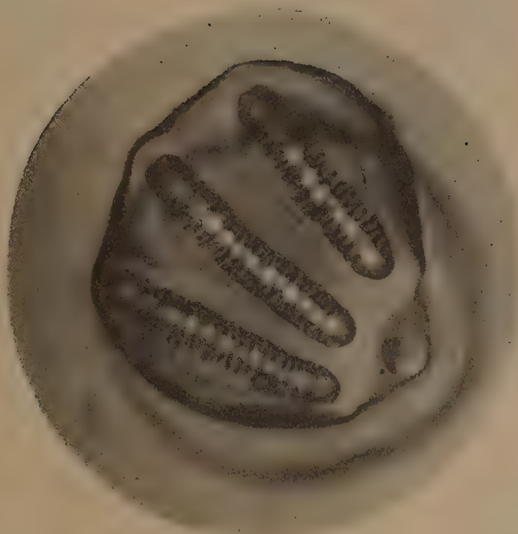


Fig. 2.

Fig. 3.

Fig. 4.

Fig. 5.

Fig. 7.

Fig. 6.

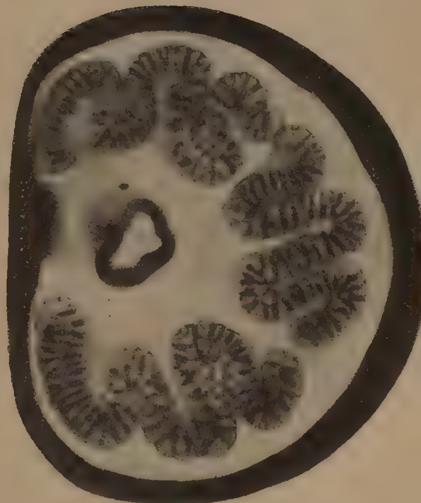


Fig. 8.

Fig. 9.

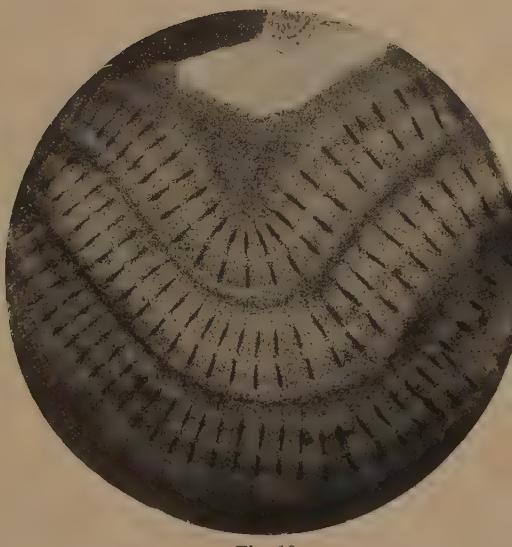


Fig. 10.

Fig. 11.

Fig. 12.

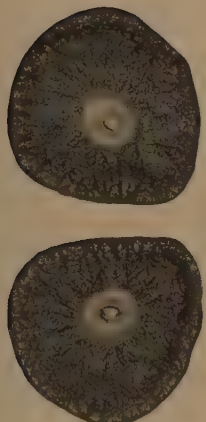


Fig. 13.

Fig. 14.

THE OCCURRENCE OF *OXYURIS VERMICULARIS* IN THE HUMAN VERMIFORM APPENDIX.

By J. ALEXANDER INNES, B.Sc.,
and A. ELMSLIE CAMPBELL, M.A., B.Sc., M.B., Ch.B.

(*From the Parasitology Laboratory, University of Aberdeen.*)

This investigation was commenced by one of us (J. A. I.) in 1910, and carried on for three and a half years. Our purpose was to determine as accurately as possible the percentage of appendices operated on for appendicitis which contained intestinal parasites. The results of a study of 100 unselected cases are given below.

Previous records.

Isolated cases of intestinal parasites in the appendix have been reported from time to time during the past years, but these have served no useful purpose except to corroborate the fact that the appendix is a not infrequent habitat of certain parasitic worms. In 1634, Fabricius ab Aquapendente mentions that he occasionally found a worm in the appendix, but as to the species of worm he makes no reference. Santorini, in 1724, made the same observation. Birch-Hirshfeld, in 1871, records an extremely rare condition of *echinococcus* of the appendix alone, without *echinococcus* of the liver.

Still (1899) was the first to investigate, with any precision, the parasitology of the appendix. Working with both normal and pathological appendices of children, he came to certain conclusions : of these, the following are the more important :

(1) That the appendix is a common habitat of *O. vermicularis* in children.

(2) That the appendix may serve, in some cases, as a breeding place for the worms.

(3) That the presence of threadworms may cause a catarrhal condition therein.

(4) That infection of the appendix with threadworms causes pain which may simulate that of appendicitis.

He states that 19 % of healthy appendices of children harbour *O. vermicularis*. Metchnikoff (1901) records a case of Trichocephalids in the appendix, and the same author describes three cases of appendicitis which he holds were due to the presence of *Ascaris lumbricoides*. Girard (1901) also reports a case of appendicitis in which Trichocephalids were found attached to the mucosa of the appendix. Hamilton Russell (1901) records an interesting case of appendicular colic which he holds was due to the presence of *O. vermicularis* in large numbers. The lumen of the appendix was dilated, the mucosa thickened and congested, and there was a considerable excess of lymphoid tissue. On inquiry, it was ascertained that all the children of the family were infected with threadworms. Von Moty (1902) attempts to make a distinction between the characters of the lesions excited by the different varieties of parasites, and finds that *Ascaris lumbricoides* seems to be more often associated with gangrenous appendicitis, while *Oxyuris* and *Trichocephalus* lead to chronic inflammatory changes.

Erdmann (1904) found threadworms in 4 out of 250 cases of appendicitis in children. In this case, however, it is probable that a thorough examination of the contents of the appendix under the microscope would have revealed a much higher percentage.

Hoepfl (1904) in Germany found that cases of appendicitis showed 21 % of the removed appendices to contain *Oxyuris*.

Patterson (1906) found *O. vermicularis* in 8 cases, and *A. lumbricoides* in 10 cases of diseased appendices. Sprengel (1906) gives Oppe's figures —threadworms found six times in 60 cases of appendicitis—and those of Rostewsew, who found *O. vermicularis* three times in the examination of 163 normal appendices.

Still (1909) records a case where 111 threadworms were found in a single appendix. In children between the ages of 2–12 years he found that 32 % were infected with *Oxyuris*, and that two-thirds of these worms were found in the appendix.

Brumpt (1910), who is an authority on this subject, goes very fully into the question in his *Précis de Parasitologie*. He examined 800 appendices obtained from autopsies at Paris, and found *Oxyuris* infection present in 3–5 % of the appendices. In the appendices of children the percentage was about four times as great, or roughly twice out of every

thirteen cases. From his examination of appendices removed for appendicitis, he found 10 cases out of 27 infected with *Oxyuris* (37 %).

In the same way Railliet (1911) found the worm 14 times in 33 cases of appendicitis (42 %), and also 58 times in a series of 119 cases (48 %); Schloss (1910) found the threadworm present in 7 % of healthy children living on the east side of New York City. Russell and Bulkley (1912), from a study of 148 unselected appendices from appendicectomies of children between the ages of two and fifteen, state that of these 19 were normal, and of the remaining 129, parasites were found in 19, of which 17 had *Oxyuris* infection, and two had *Trichocephalus* infection. The number of worms present varied from one to thirty-five. In eight cases the males outnumbered the females. Out of 19 normal appendices, parasites (*Oxyuris*) were found in three. Four adult cases of *Oxyuris* appendicitis were also examined. They classify their cases in the following manner:

	Oxyuris	*Trichoceph.*	No infection	Total
1. Acute catarrhal appendicitis,				
(*a*) Children	14	1	5	20
(*b*) Adults	4	0	0	4
2. Chronic appendicitis	0	0	20	20
3. Acute suppurative	0	0	25	25
4. Acute gangrenous	3	1	60	64
5. Normal appendices	3	0	16	19
	24	2	126	152

Ney (1912) cites two cases of appendicitis in which there were in the one case, two, and in the other, five *Oxyuris* in the appendices. He also reports that in a series of 100 appendices removed at the Hebrew Hospital, only three contained threadworms.

In the Clinical Records of the *Edinburgh Medical Journal* (1913) details are given of 14 cases in which various nematodes were found in the appendix. These cases may be summarised:

A. *Ten Cases of Appendicitis.*

No.	Sex of patient	Age (years)	No. of *Oxyuris* found	Type of appendicitis
1	M	8	Large number	Acute
2	M	14	20–30	,,
3	M	8	Large number	Recurrent
4	M	38	Several worms	,,
5	F	15	7–8	,,
6	M	9	Numerous worms	,,
7	M	18	Large number	Chronic
8	F	15	,,	,,
9	M	19	Numerous worms	,, ?
10	F	21	,,	,,

B. Case of a female, age $5\frac{1}{2}$, operated upon for intussusception, and in whose appendix several *Oxyuris* were found.

C. Case of a female, aged 7, operated upon for appendicitis, appendix found to be normal, but was packed with threadworms.

D. Case of a female, aged 32, operated upon for recurrent appendicitis. The appendix was ulcerated at one point, and contained four *Ascaris lumbricoides*.

E. Case of chronic appendicitis (no clinical history given) operated upon and the appendix found to contain one *Trichocephalus trichiurus*. The appendix was also the site of a primary carcinoma.

These selected cases, although of much interest individually, do not help towards forming an estimate of the percentage of infected appendices, but they bear out the suggestion of von Moty (1902) that different varieties of parasites may cause different lesions of the appendix. Von Moty suggests that *Ascaris lumbricoides* causes an acute inflammation going on to gangrene, and that *O. vermicularis* and *T. trichiurus* lead to a more chronic inflammatory condition. Our own cases confirm his suggestion regarding the inflammatory changes produced by *Oxyuris*.

With regard to the records of isolated cases of appendicitis in which *Oxyuris* have been found in the appendix, it will be sufficient if we group these together. A bibliography of these cases has been appended for further completeness. Wakefield (1908), Wagener (1906), Walther (1905), report single cases, but no description of the gross or microscopic lesions is produced. Culhane (1910), Martin (1907), von Moty (1902), Pabeuf and Dubois (1908), Ashhurst (1909), Bégouin (1902), report clinical cases and describe the histological changes found. They fail to establish any relationship between the parasites and the changes described. Winkler (1910), Hippius and Lewinson (1907), Weinberg (1907), Romanovitch (1911), Brumpt and Lecène (1910), Galli-Valerio (1903), report single cases of *Oxyuris* appendicitis in which the parasite is shown to be the actual cause of the disease. Wilson (1912), Burgess (1912), Grippen (1912), Macdonald (1912), etc. also report cases of *Oxyuris* in the appendix. Unterberger (1908) records two cases of *Oxyuris* appendicitis accidentally discovered at autopsies.

Trichocephalus trichiurus in the Appendix.

In view of the fact that *T. trichiurus* was not found present in any of our cases, we give below some of the statistics compiled by other investigators with regard to this worm. Brumpt (1910) quotes the following:

"On 1600 medico-legal autopsies performed at Chicago, Mitchell never found a single helminth." Lejar (1897), Guinard (1900) and Girard (1901) had cases of *T. trichiurus* in the appendix. Ménétrier (1909) published several cases: Brumpt found the worm in 4 % of cases (autopsies), Railliet only once found the nematode in 119 cases, but the ova were often present in the appendix. In a table compiled by Blanchard and Braun in 1880, they give the percentage of infected caeca at Greenwich as 68 % to 75 %, so that in all probability the appendix infection must have been correspondingly high.

Scope of Present Investigation.

This comes under five heads:

To determine (1) The percentage of infected cases.
(2) The relationship of age to infection.
(3) The nature of the infecting parasite.
(4) The relationship of the parasite to appendicitis.
(5) The probable mode of infection.

Methods:

We have examined over 150 appendices representative of all types of appendicitis, but for the sake of accuracy the first 50 or 60 appendices examined were rejected. The chief reason for this was that we might become thoroughly accustomed to make a reliable examination, to identify quickly and definitely any worms, if these were present, and to attain some degree of precision in the enumeration of the parasites. It also gave us an opportunity of testing various methods for the examination of appendices. Ultimately the following procedure was adopted, and the next series of 100 appendices was examined in this manner. Every appendix was examined within two to four hours after its removal from the body, and the routine examination was made in almost all cases in the laboratory.

The appendix was slit open along the attachment of the meso-appendix, from the proximal end. Great care was taken in making the first cut at the proximal end, as we have often found the worms to be most numerous at that point. In many cases, where single worms were found, they were found in that region. Having laid the appendix open, we transferred it carefully to a large Petri dish half filled with normal salt solution. If worms were present, the females stood out clearly, and these were removed and counted. The mucosa of the appendix

was then scraped off, and left in the salt solution, while the appendix was removed. The Petri dish with the saline and mucous scrapings was examined microscopically under a low power, and immature females and males were "spotted," and counted as they were removed. In many cases, to make more certain, we examined the contents of the Petri dish, part by part in a watch glass.

The method recommended by Brumpt (1910) of placing the mucous scrapings between two glass plates, we did not find very satisfactory, as it was liable to crush the worms, and to introduce errors in counting. It is, however, an excellent method for determining the fact of the presence of worms in the appendix.

The material was obtained from appendicectomies performed at the Royal Infirmary, and in two cases from the Royal Hospital for Sick Children. All types of appendicitis were examined, but normal appendices removed during the course of other operations, such as laparatomies, although investigated, have not been used in compiling the results. In no case did we find worm infection in a healthy appendix.

Results of Investigation.

The types of appendicitis studied were classified under five groups, special attention being given to the "*recurrent*" type, as this was found to show the highest percentage of infected appendices.

The term "*recurrent appendicitis*" has been applied to that type which has a history of a year's duration or more, and in which there have been several more or less severe attacks of appendicitis at varying intervals.

The number of cases in each group was as follows:

(*a*)	Acute catarrhal appendicitis	30
(*b*)	Subacute catarrhal appendicitis	22
(*c*)	Chronic appendicitis	14
(*d*)	Gangrenous appendicitis ..	8
(*e*)	Recurrent appendicitis ..	26
	Total	100

Out of these cases, 17 were found to harbour *O. vermicularis*, while in no case were trichocephalids or other worm parasites found. The ova of *Oxyuris* were found in two of these cases, but as in each there was also a ruptured mature female worm, no stress can be laid on this fact. The ova of *T. trichiurus*, or of other nematodes, were not seen.

The details of the infected appendices are :

No.	Sex of patient	Age	No. of *O. vermicularis* Males	Females	Total	Type of appendicitis
1	F	22	0	1	1	Recurrent
2	F	7	10	10	20	Acute catarrhal
3	M	22	5	14	19	Recurrent
4	F	15	1	3	4	Recurrent
5	M	12	21	21	42	Recurrent
6	F	19	1	0	1	Subacute catarrhal
7	F	17	0	1	1	Recurrent
8	F	24	0	1	1	Recurrent
9	F	23	0	1	1	Recurrent
10	M	23	1	1	2	Subacute catarrhal
11	M	11	1	11	12	Recurrent
12	F	6	0	4	4	Acute catarrhal
13	F	17	1	1	2	Recurrent
14	M	21	0	2	2	Recurrent
15	F	12	2	4	6	Recurrent
16	F	23	0	1	1	Subacute catarrhal
17	M	18	0	2	2	Recurrent

It is a matter of some importance to note the various sizes of worms found, in connection with the degree of maturity attained by them. The length of the female worm is given by authorities as from 9 to 12 mm. and that of the male worm as from 2 to 5 mm. Out of the 121 *Oxyuris* measured, no female worm exceeded 9 mm. in length, and only one specimen gave that measurement. The average length of the female was from 5 to 6 mm., and 3 mm. in the case of the male.

Judged by size, the worms found in the appendix were not mature, but the males had reached a further state of development, on an average, than the females.

Still (1909) discusses this point of immaturity, and holds that this is a good reason for believing the appendix to act as a breeding ground for *Oxyuris*. He doubts if infection is kept up solely by the repeated swallowing of ova.

Percentage of Infected Cases.

The percentage of infection, viz., 17 % in all cases of appendicitis, is undoubtedly lower than what it would be if the appendices had been examined under conditions which excluded any possible source of error. In spite of every means being taken to attain the greatest accuracy, it

is certain that many male *Oxyuris* have been missed and not enumerated, especially in cases where no female worms were present to definitely establish the fact of the presence of worms in the appendix. We could devise no plan which might ensure *every* worm being counted. Again, we could not interfere with the preparation of the patients for operation. This preparation included the routine administration of purgatives, and also, in most cases, of a turpentine enema, given a few hours before operation. Both these measures—vermifugal in their action—could quite easily dislodge any of, or all, the worms in the appendix, and in some cases our examination was negative when it might have shown the presence of worms if no preparatory measures had been taken.

These facts must be noted in considering the percentage.

With regard to the comparison of statistics available for *O. vermicularis*, we tabulate below, and compare with our results the findings, as far as they have been obtainable, of other investigators.

Railliet	42–48 %	in appendicitis
Brumpt	37–40 %	,, ,,
,,	15 %	,, normal appendices (children)
,,	3–5 %	,, normal appendices (adults)
Hoepfl	21 %	,, appendicitis
Still (1909)	20 %	,, appendicitis of children
,, (1899)	19 %	,, normal appendices (children)
Innes and Campbell	17 %	,, appendicitis
Russell and Bulkley	15 %	,, appendicitis of children (including two *trichocephalids*)
Oppe	6 %	,, appendicitis
Ney	3 %	,, appendicitis
Rostewsew	1·8 %	,, normal appendices (adults)
Erdmann	1 %	,, appendicitis of children

As previously stated, Erdmann's figure is unreliable, because a thorough examination was not made in every case.

One must also bear in mind that many of the percentages in the above table were arrived at from a study of a small number of appendices, and therefore the figures are not strictly accurate in every case.

It will be seen that the figures given vary greatly from exceedingly low percentages to correspondingly high ones, and whether this has to do with climatic conditions it is not yet possible to say, but in every instance it seems that the percentage of worms is higher in cases of appendicitis than in those of normal appendices. More statistics, however, must be available before anything definite can be put forward.

Relationship of Age to Infection.

Our series of cases was mainly composed of adults, whose ages ranged from 15 to 53 years, and the commonest age of infection with *Oxyuris* in the appendix seems to be between the 21st and 24th years. At present it would be difficult to say with certainty that children show a higher percentage of infection, but probably such is the case. The figure given by Still (1909) of 20 % is higher than the average figure for adults in this country, but Brumpt (1910) and Railliet (1911) both give much higher figures for adults in France. This question, therefore, still remains open.

Nature of Infecting Parasite.

In the course of this investigation, only one species of parasite was met with, viz.: *O. vermicularis*. We understand, however, that at the Royal Infirmary one or two cases have been found of *Trichocephalus trichiurus* in the appendix. Undoubtedly the occurrence of this worm in cases of appendicitis is very rare in this part of the country.

Other observers note that *T. trichiurus* is much less frequently found than *Oxyuris*, but it seems strange that in 1880 Blanchard and Braun should have found the worm in the caecum 11 times out of 16 cases examined by them at Greenwich. No record of *Ascaris lumbricoides* having been found in the appendix could be obtained.

Relationship of the Parasite to Appendicitis.

This opens up a much disputed question, and as it lends itself to wide discussion, we propose to deal with this in a separate contribution which will be published shortly by one of us (J. A. I.). It will be sufficient to remark here that we think it very probable—in view of collected clinical data—that worm infection of the appendix gives rise, in many cases, to certain symptoms and to a definite type of history which are of diagnostic importance. From the table of cases investigated by us, it will be evident how largely recurrent appendicitis bulks in the total series, and also that of the infected cases, 65 % were of the recurrent type.

Gangrenous appendices never showed the presence of any worm parasites, but we corroborate the fact already pointed out by von Moty (1902) that the subacute and chronic inflammatory changes are more characteristic of *Oxyuris* infection.

An interesting condition of the infected appendix was the occurrence at definite areas of numerous small, discrete, punctiform haemorrhages, which suggested the points of attachment of the nematodes.

Probable Mode of Infection.

This was the least satisfactory part of the whole inquiry, for in most cases nothing definite could be elicited from the patient regarding even his or her own opinion as to how worm infection took place. In two cases there was a certain history of worm infection, which had probably been continued through auto-infection. In one of these cases there was a family history of infection, and it is interesting to note that in this family three girls had appendicitis. Information as to the exact contents of the appendices was available only in the infected case. Still (1909) remarks, "not very rarely more than one child in a family is suffering from threadworms; but this does not happen with sufficient constancy to justify the assumption that such a source (of infection) is the usual or even a common one."

In many of the cases there was a history of chronic nail-biting, and this could quite easily give rise to a fresh infection or continue an already existing one, but as Still says: "The number of ova on the fingers must be very large and easily demonstrable." He found, however, that in an experiment carried out on five children who were passing large numbers of threadworms that the dirt on the finger-ends and under the nails showed only one solitary ovum in the case of one child out of five.

One infected patient had a great passion for eating raw fruit, and infection may have resulted from eating contaminated oranges or apples, etc.

Another patient employed at a farm house was very fond of animals, and in her own words: "held a lot of work with cats and dogs." In this case it is possible that infection was carried by these animals from outside sources.

Conclusions.

1. That the percentage of appendices from cases of appendicitis infected with *O. vermicularis* is a fairly high one. In Aberdeen 17 % were found to be infected.

2. That normal appendices show a much lower percentage of infection.

3. That the appendices of children probably show a higher percentage of infection than those of adults.

4. That the recurrent type of appendicitis is most frequently associated with *Oxyuris* infection.

5. That there is probably a clinical type of *Oxyuris* appendicitis.

6. That the suppurative type of appendicitis has practically no relationship to *Oxyuris* infection.

7. That *Trichocephalus trichiurus* is not commonly found in the appendix.

We have to record our indebtedness to the staff of the Aberdeen Royal Infirmary, and of the Aberdeen Royal Hospital for Sick Children for help given towards the collection of material for this investigation, and also to Dr John Rennie for many valuable suggestions.

REFERENCES.

Ashhurst (1909). *Amer. Journ. of Med. Sci.* cxxxviii. 583.
Bégouin (1902). *Gaz. Hébd. Soc. Méd. de Bourdeaux,* xxiii. 363.
Birch-Hirshfeld (1871). *Archiv f. Heilkunde,* 191.
Brumpt (1910). *Précis de Parasitologie,* 355–358.
Burgess (1912). *Brit. Med. Journ.* i. 415.
Clinical Records (1913). *Edinburgh Med. Journ.* i. 437.
Culhane (1910). *Journ. Amer. Med. Assoc.* liv. 48.
Erdmann (1904). *New York Med. Journ.* lxxix. 537.
Galli-Valerio (1903). *Centralbl. f. Bakteriol.* xxxiv. 350.
Girard (1901). *Ann. Inst. Pasteur,* xv. 440.
Grippen (1912). *Brit. Med. Journ.* i. 1072.
Hippius and Lewinson (1907). *Deutsche med. Wochenschrift.* xxxiii. 1780–1782.
Hoepfl (1904). *Archiv f. klin. Chir.* lxxiii. 100.
Macdonald (1912). *Brit. Med. Journ.* i. 485.
Martin (1907). *Montpel. Méd.* xxiv. 531–537.
Metchnikoff (1901). *Journ. des Praticiens,* xv. 185.
—— (1901). *Bull. Acad. Méd.* xiv. 301.
Moty, von (1902). *Echo Méd. du Nord,* vi. 217.
—— Quoted in *Lancet* (1902), ii. 1211.
Ney (1912). *Johns Hopkins Hosp. Bull.* xxiii. 123.
Pabeuf and Dubois (1908). *Bull. Méd.* xxii. 153.
Patterson (1906) *Amer. Journ. Med. Sci.* cxxxi. 859.
Railliet (1911). *Compt. rend. Soc. de Biol.* lxx. 310.
Romanovitch (1911). *Compt. rend. Soc. de Biol.* lxx. 122.
Russell (1901). *Internat. Med. Journ. of Australia,* Dec. 1901.
Russell and Bulkley (1912). *Journ. of Exper. Med.* xv. 225.
Schloss (1910). *Amer. Journ. Med. Sci.* cxxxix. 675.

Sprengel (1906). *Deutsche Chir.* Stuttgart, S. 182.
Still (1899). *Brit. Med. Journ.* I. 898.
—— (1909). *Common Disorders and Diseases of Childhood,* London, 267, 271
Unterberger (1908). *Centralbl. f. Bakteriol.* Abt. 1, XLVII. 495.
Wagener (1906). *Virchow's Arch.* CLXXXII. 145.
Wakefield (1908). *Jour. Amer. Med. Assoc.* L. 1904.
Walther (1905). *Bull. et Mém. Soc. de Chir.* XXXI. 355.
Weinberg (1907). *Ann. Inst. Pasteur,* XXI. 417.
Wilson (1912). *Brit. Med. Journ.* I. 829.
Winkler (1910). *Die Erkrankungen des Blinddarmenganges,* Jena, 234.